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Original Communications

TWO INTERESTING BENIGN LUNG TUMORS OF CONTRADICTORY HISTOPATHOLOGY

REMARKS ON THE NECESSITY FOR MAINTAINING THE CHEST TUMOR REGISTRY

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IN ADDRESSING you today, I am reporting two interesting cases very similar in clinical, laboratory, and x-ray findings, but pathologically quite distinct.

It occurred to me that I might use the report of these two cases, the pathology of which is controversial, and the paper, "Adenoma of the Bronchus," by Dr. Stephens and Dr. Goldman, from our clinic, as arguments for the preservation of our Chest Tumor Registry. I think that all of us will agree that the maintenance of the Chest Tumor Registry by this Association is advisable. The nomenclature, the classification, and the study of the origin of tumors of the chest and lung are still hazy. Pathologists differ in their diagnosis of these tumors, as illustrated in the cases presented today. This difference of opinion extends also as to their malignancy. This is a serious matter which we, as clinicians, should attempt to remedy.

The essence of the plan is to have this work carried on by the associate members who will call meetings once, or at most twice, a year, at which time the different members will report their cases. In the plan suggested seven regions or seven cities are designated as centers where these groups will meet. The members will choose their most convenient meeting place. Members of pathologic societies or pathologists will be invited to attend in the different regions, and the reports of the cases, pathologic findings, discussions, and specimens

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will then be sent to the central registry for elaboration. In this way, without much effort, a large number of cases will be collected in a comparatively short time.

The following advantages would accrue. The Association would be doing a worth-while piece of work which is undoubtedly necessary. A large number of cases will be reported without much effort. The reports of different pathologists will be available, and these opinions could be used by the central depository for the final diagnoses. The membership of this Association would be benefited in no little degree, and the pathologists throughout the country would also be educated in this rather obscure subject.

This plan would also give other advantages, possibly of secondary importance, but none the less valuable. Our membership would get together oftener than once a year at the general meeting; the plan would create intercourse between the different members of the group, and the associate members participating actively in this work would increase measurably their interest in the Association. It would also give an opportunity for the active members to become acquainted with the abilities and qualifications of the associate members, thus improving the choice for active membership.

The Council has accepted this plan in essence, and I wish to thank them for their cooperation in its further development.

REPORT ON TWO INTERESTING BENIGN LUNG TUMORS OF CONTRADICTORY HISTOPATHOLOGY

As stated before, I am reporting to you today the cases of two patients with very remarkable tumors, who came to me within a short space of time. After I had operated upon the first, I thought it would be a long time before I saw another similar one, but as often happens in the practice of medicine, only a few months elapsed before I was called in consultation on an almost similar case.

I was able, therefore, in the second case to carry out a more intensive examination than had been possible in the first. Strangely enough, however, despite the similarity in the x-ray picture and in the clinical symptoms, the histopathology of each was very dissimilar, although one cannot quite free himself from the thought that they must have had a somewhat similar origin and that the route of absorption, however it came about, occurred through the same channels.

CASE REPORTS

CASE 1.—The first case I saw with Dr. Edward B. Shaw at the Children's Hospital. The patient was a girl (S. M.), aged 5 years, who was perfectly well until Feb. 12, 1937, when she became ill with a cough, moderately productive expectoration, elevated temperature, malaise, nausea, and, at times, vomiting. The child was known to have a congenital heart defect, and the pediatrician on examination discovered a sore throat and some slightly enlarged lymph nodes in the neck. This acute illness practically subsided by the fifth day and not much more was thought of it, nor were we sure that this was the beginning of her real illness. Following this

it was noted that she failed to get back to her normal status. She was listless, anemic, had a slight daily elevation of temperature, and was not interested in her play. As time went on, the temperature became elevated to between 100 to 101° F., and she lost weight. Her brother, in the meantime, had returned from the hospital after an attack of pneumonia, and it was thought that perhaps he had brought infection into the house.

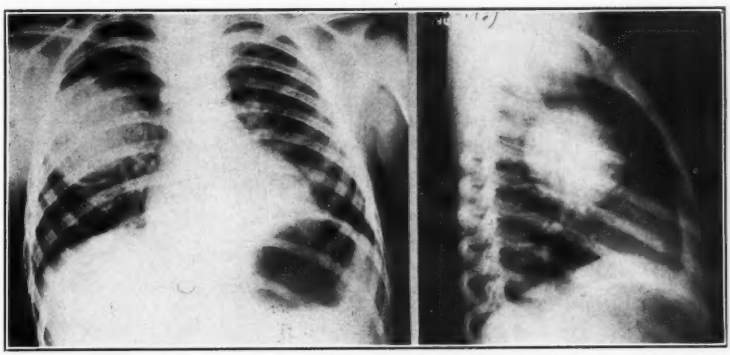

Fig. 1. Fig. 2.

Fig. 1.—Case 1, S. M., white female, aged 5 years. Discrete globular tumor in the right upper lobe. No atelectasis or pneumonitis. March 15, 1937.
Fig. 2.—Case 1. Lateral view.

Fig. 3.—Case 1, S. M., photographed ten days postoperatively.

She was admitted to the Children's Hospital where an x-ray of the chest was taken, and a mass was discovered in the right upper lobe (Figs. 1 and 2). This mass was globular in shape (we have called it a tennis-ball tumor), discrete, well defined and outlined. It had a fairly even density. However, at the lower border it seemed to show evidence of a capsule. The surrounding lung was not involved except, perhaps, by a slight pressure condensation from the tumor. There was no atelectasis, pneumonitis, or other inflammatory reaction. A definite diagnosis was

not made. Some consideration was given to the question of interlobar fluid or loculated empyema. The mass was punctured by a needle for purposes of biopsy, but the findings were negative except that no pus was found. No specimen could be obtained for examination.

A few days later diagnostic artificial pneumothorax was done, and x-ray pictures showed that the tumor had now dropped down with the collapse of the lung, lying almost on the diaphragm. This proved definitely that the tumor was in the lung parenchyma and was not springing from the chest wall.

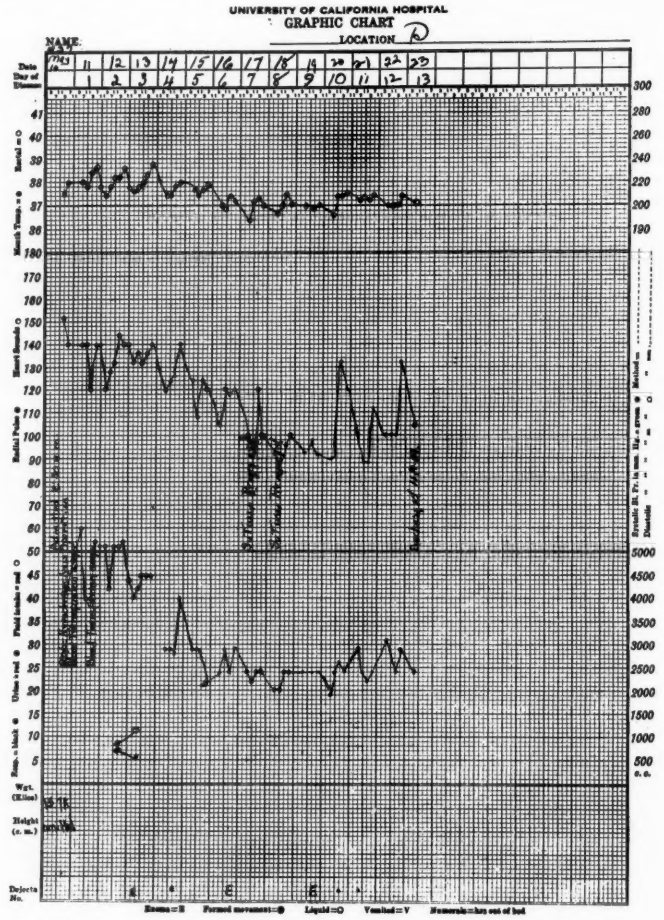

Fig. 4.—Temperature chart, Case 1. Patient discharged from the hospital on the thirteenth day. Smooth recovery.

The patient was then permitted to return home, during which time the air was allowed to absorb. She continued to feel weak, with daily elevations of temperature; slight clubbing of the fingers appeared; and the moderately productive cough continued with malaise and night sweats. There was no hemoptysis and only slight dyspnea. The loud systolic murmur from her congenital heart defect remained about the same without any associated symptoms.

Physical Examination.—The tumor could not be outlined. No râles were heard. Breath and voice sounds were normal, and the heart was not enlarged. There was no cyanosis. Blood count was as follows: hemoglobin, 52 per cent; red blood cells 2,930,000; white blood cells 11,000, with 66 per cent polymorphonuclears. A later blood count showed that the leucocyte count had risen to 15,000.

Operation.—On May 10, 1937, the patient entered the University of California Hospital for operation. Under avertin, nitrous oxide and ether anesthesia, a right intercostal incision was made in the sixth interspace, and a right upper lobectomy was performed. There were many loose, filmy adhesions between the upper lobe of the lung at the site of the tumor and the parietal pleura. These were separated without difficulty, and there appeared a whitish, yellow, apparently encapsulated tumor mass, which seemed to involve a considerable part of the right upper lobe. It was well defined and not infiltrating. The upper lobe was easily separated from the middle and lower lobes. The pedicle of the upper lobe was mobilized; a tourniquet was placed around the pedicle and the lung was removed by a wedge-shaped incision. Vessels of the pedicle were tied, and the pleura was closed over the stump. The patient stood the operation well. A transfusion of 250 c.c. of blood was given immediately after the operation and repeated two days later. The chest cavity was closed without drainage. Aspiration was done on three occasions with removal of a small amount of air and fluid. The patient had no serious reaction. She became afebrile on the sixth postoperative day and was discharged on the thirteenth day with primary union (Figs. 3 and 4).

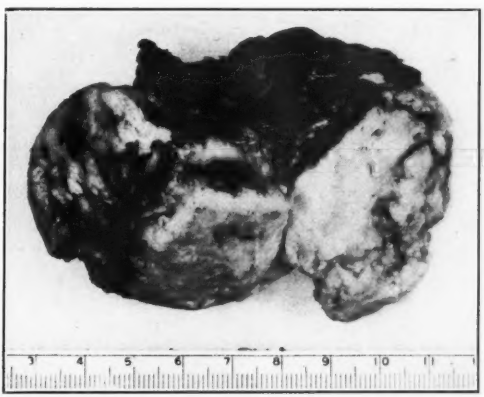

Fig. 5.—Case 1. Tumor showing apparent encapsulation with a few necrotic areas filling a large part of the right upper lobe of the lung.

Section of the tumor at the operating table showed what appeared to be a well-encapsulated, rounded tumor mass about 5 cm. in diameter (Fig. 5). On section, this showed a soft, pinkish tan, somewhat gelatinous tumor with areas of softening and some hemorrhage. There were strands of fibrous tissue here and there, and the surrounding lung was compressed (Figs. 6 and 7).

The first diagnosis of this tumor from the pathologist was lymphogranuloma of the lung. On later studies this was changed to subacute granulomatous mass from the right upper lobe.

Dr. G. Y. Rusk submitted the following report: "Microscopic examination of a number of sections of fairly large circumscribed, but not encapsulated, mass from upper lobe of right lung shows the background of the mass to be composed of fine strands of connective tissue and a number of fine vessels in a background varying in compactness and, in some regions, appearing relatively

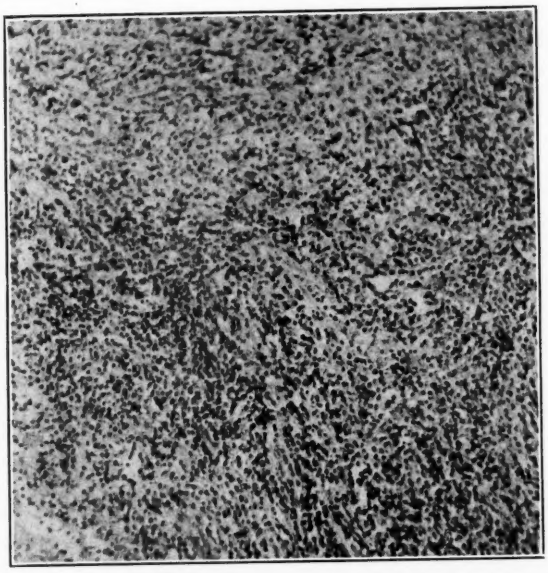

Fig. 6.—Case 1. Low power photomicrograph.

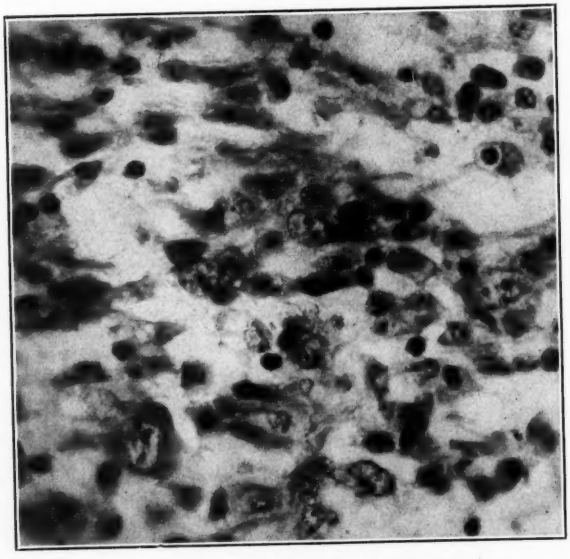

Fig. 7.—Case 1. High power photomicrograph.

edematous. This framework is extensively infiltrated by mononuclear cells and lymphocytes, growing for the most part more or less diffusely between the fibroblastic tissue, and in some areas forming small nodules. Associated with these are plasma cells in large numbers, trailing along in varying numbers with the lymphocytes. Occasionally a few mononuclear cells, large and with eosinophilic cytoplasm, are found along the vessels. In some regions there is a distinct thick layer of fibrous tissue between the granulomatous mass and the lung structures, the latter showing atelectasis, apparently due to pressure, but without chronic organizing or interstitial pneumonia as might be found. Careful search for mitotic figures in the mass proper is entirely negative, and the process is considered entirely on an inflammatory basis and no evidence of malignant neoplasm is found. Diagnosis: Subacute granulomatous mass from uppper lobe of right lung.''

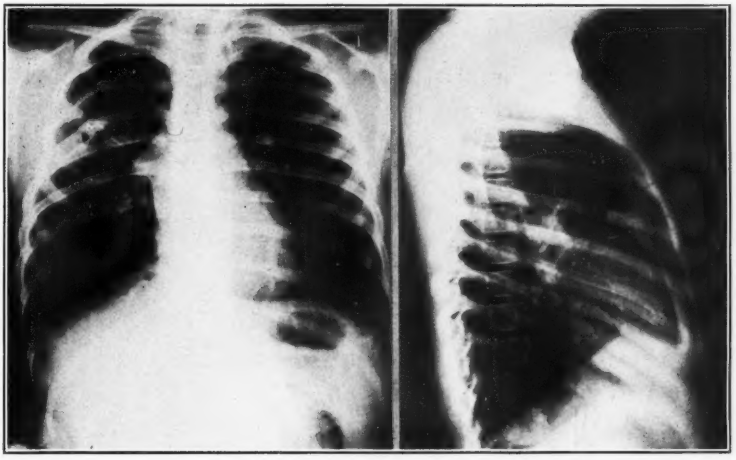

Fig. 8. Fig. 9.

Figs. 8 and 9.—Case 1, S. M., June 15, 1939. X-ray made two years postoperatively shows patient symptom free after right upper lobectomy for granuloma. No evidence of recurrence.

The history of this case and specimens of the tumor were sent to several prominent pathologists, and the following pathologic diagnoses were made: (1) lymphogranuloma of lung; (2) mesoblastic tumor growth with lymphogranuloma questioned and possible virus etiology suggested; (3) mixed tumor; (4) subacute granulomatous, nonmalignant, nonneoplastic growth; (5) plasma cell granuloma.

We accept the diagnosis of a subacute granulomatous mass with some doubt. Clinically it seems to be a true neoplasm. Where to draw the line between true neoplasms and granulomas is difficult. It is unfortunate that no cultures were taken at the operating table, as we considered this a true tumor. Lending support to this idea is the fact that there were no glands at the root of the lung nor in the mediastinum so far as we could tell.

X-ray pictures taken some two years after the operation show the lungs to be clear (Figs. 8 and 9). The patient has remained in perfectly good health and has gained in weight. The clubbing of the fingers is gradually disappearing, and she is developing normally.

Case 2.—M. B., aged 11 years, was seen in consultation a few months later at the Franklin Hospital, with findings and clinical signs almost exactly similar to those

of the first case except that the girl was more acutely ill. This patient was essentially well until December, 1937, six months before she was seen. At that time it was noted that she had become less active than usual, tired readily, felt restless, and appeared generally below par. The patient was growing rapidly but failed to gain weight correspondingly. Her general condition became worse, despite tonics, rest, and supporting measures. She remained ambulatory, however, until April, 1938, when she was examined by another physician who thought she might be suffering from rheumatic fever. At this time she had fleeting pains in her extremities and ran a daily temperature of from 101 to 104½° F. She was put to bed, but the temperature continued. She was then removed to the Franklin Hospital in San Francisco where x-ray pictures were taken, and I saw her in consultation with Dr. DiGrazia, Dr. Lucas, and Dr. Shaw.

Here again a rounded mass was found in the right upper lobe almost similar to the case just reported, round, discrete, apparently encapsulated without involving the surrounding parenchyma (Figs. 10 and 11). At no time during the patient's illness had there been cough, sputum, or hemoptysis.

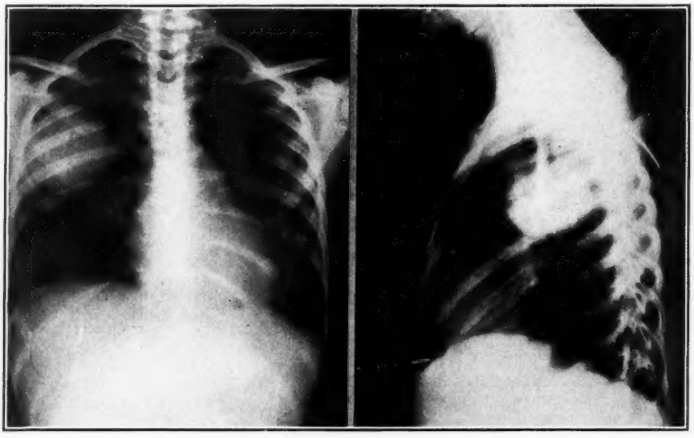

Fig. 10. Fig. 11.

Fig. 10.—Case 2, M. B., white female, aged 12 years. Posteroanterior view May, 10, 1938, showing dense, circumscribed, discrete, tennis-ball shadow without involvement of the lung proper. No atelectasis or pneumonitis.

Fig. 11.—Case 2. Lateral view.

Physical Examination.—The patient was a thin, somewhat underdeveloped child 12 years of age. She appeared to be very sick; she was too tired to talk and lay curled up in bed, interested in nothing that was going on. She was running a high swinging temperature with a rapid pulse but complained of no pain. Some discrete, moderately enlarged cervical and inguinal lymph nodes were palpable. The mucous membrane was pale. Her tonsils had been removed. There was some slight impairment of resonance over the right apex posteriorly. Breath sounds were vesicular throughout, and no râles were heard. Extremities were very thin with slight clubbing of the fingers. Reflexes were normal.

Laboratory reports showed that the echinococcic skin test was negative. Blood count was: hemoglobin, 74 per cent; red blood cells, 3,900,000; white blood cells, 21,600 with a differential of 97 per cent polymorphonuclears, 79 per cent filaments, 8 per cent nonfilaments, 12 per cent lymphocytes, 7 per cent monocytes, 1 per cent eosinophiles, 1 per cent basophiles.

Bleeding time was 45 seconds; coagulation time, 3½ minutes; vital capacity, 1,600; human and bovine tuberculin reaction, negative; sedimentation time, 18 mg. in 9 minutes; urinalysis negative. The patient's blood was Type IV.

She was transferred to the University of California Hospital for operation. On May 12, 1938, a transfusion of 250 c.c. of whole blood was given. She continued to have a high temperature, and on the morning when operation was set, she was so ill I felt compelled to defer it. Five days later, however, despite the temperature and the poor condition of the patient, it was considered advisable to explore the right chest.

Operation was performed May 18, 1938, under gas, oxygen and ether positive pressure anesthesia. The right chest was opened through a long intercostal incision on the right side in the sixth interspace. A reddish-purple, rounded mass was discovered in the right upper lobe, about 8 or 6 by 6 cm. in size. The tumor projected beyond the surface of the lung, somewhat mushroomlike, and extended into the lung for quite a distance. It seemed to be well encapsulated on its external surface. It was felt that this tumor could be removed by resection rather than by lobectomy, and a generous margin of lung parenchyma was resected with the tumor (Fig. 12). The cut edges of the lung were closed with running stitches and the raw edges buried by inverted mattress sutures. The lung was then expanded, and the wound was closed in layers without drainage. The patient left the table in very good condition. She was given a transfusion of 250 c.c. of whole blood.

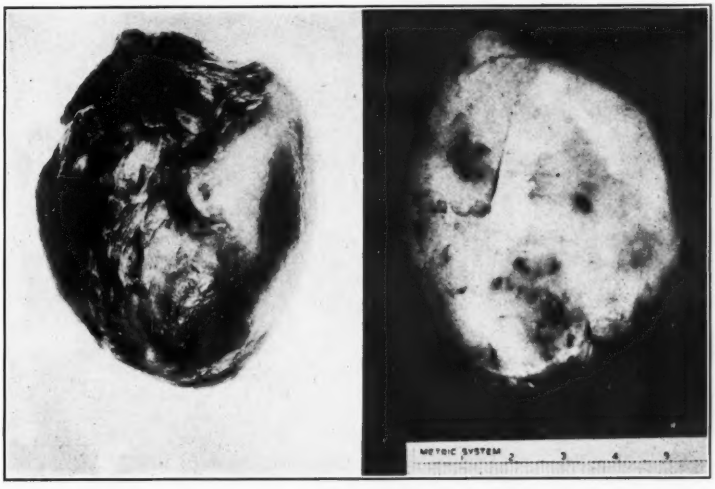

Fig. 12.—Case 2. Specimen removed by excision. Circumscribed mass projecting from the periphery and extending into it.

Postoperative Course.—The patient was never in a state of shock at any time and had very little cyanosis, no respiratory distress, and moderate abdominal distention for three days which cleared rapidly. There was hardly any rise of temperature, and after three days she ran an entirely uneventful course (Fig. 13). Thoracentesis was done on the second day, and 250 c.c. of air were withdrawn. On the fifth day this was repeated with return of 250 c.c. of straw-colored fluid and some air. Culture of the fluid was sterile.

Again in this case, a striking feature was the postoperative course. There was immediate drop in the temperature reactions, the patient appeared less toxic, and the improvement was rapid. X-ray examination of the chest on the seventh post-

operative day showed that the right lung had expanded considerably, and she was discharged on the eighteenth day perfectly well.

On account of the similarity of this tumor to the first case every effort was made to cover the bacteriology, as it was thought that this also would be a granuloma and not a neoplasm.

The tumor was macerated by means of sterile sand. Gram- and acid-fast stained smears showed no organisms. The following culture media were inoculated: Avery blood broth; surface of blood agar plates; blood agar slants, aerobic

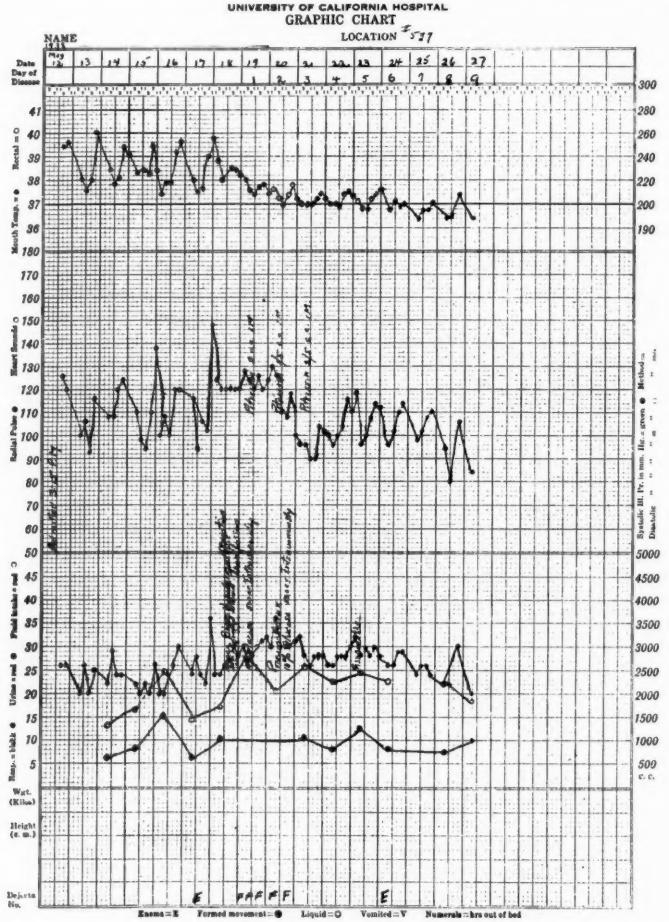

Fig. 13.—Clinical chart, Case 2. Note the immediate postoperative drop of the temperature.

and anaerobic; minced beef heart media; three bottles of brain broth—(1) at ordinary oxygen tension, (2) at reduced oxygen tension, and (3) anaerobic Stewart's synthetic broth for fungi. Two mice were inoculated intraperitoneally. The animals survived the inoculation and were etherized and autopsied with negative findings. Two guinea pigs were inoculated subcutaneously. One was

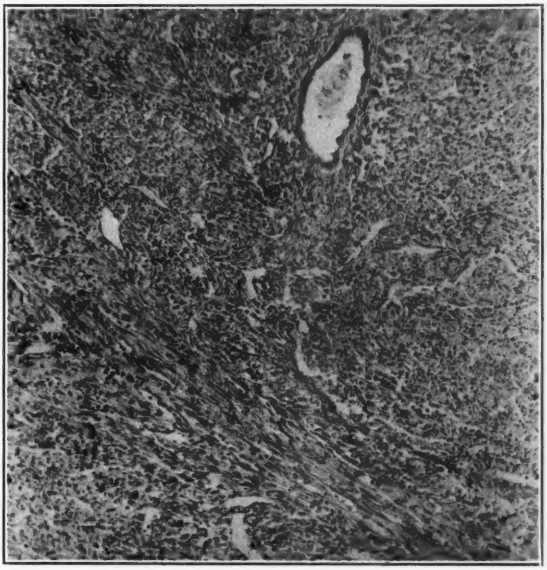

Fig. 14.—Case 2. Low power photomicrograph. One glandlike structure is seen surrounded by interlacing muscle bundles.

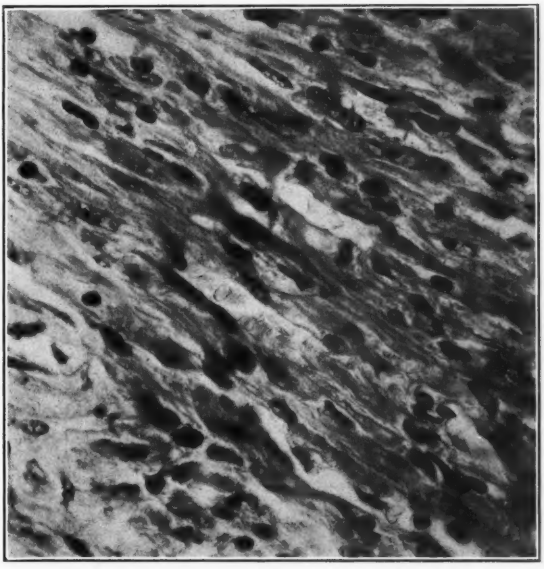

Fig. 15.—Case 2. Oil immersion. Muscle cells show a faint linear striation.

etherized on June 8, and the autopsy finding was negative. Blood cultures remained sterile after nine days, both aerobic and anaerobic. Blood serum was negative.

From surgical pathology the diagnosis was mesothelioma of the lung. On review this was changed to myoma of the lung with lymphocytic infiltration, small areas of fibrosis and of necrosis, and richly vascular stroma (Figs. 14 and 15).

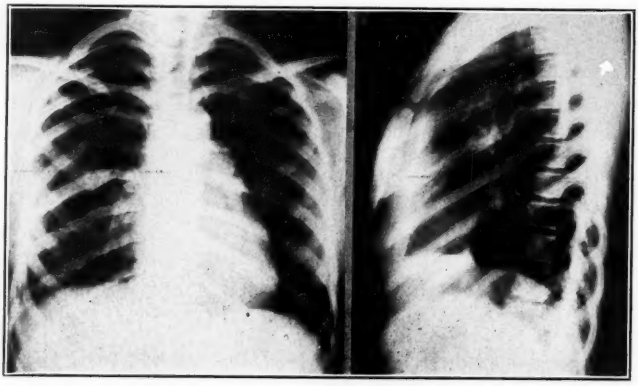

Fig. 16. Fig. 17.

Figs. 16 and 17.—Case 2, M. B., June 8, 1939. X-ray made one year after operation for myeloma of lung. Patient symptomless and gaining weight.

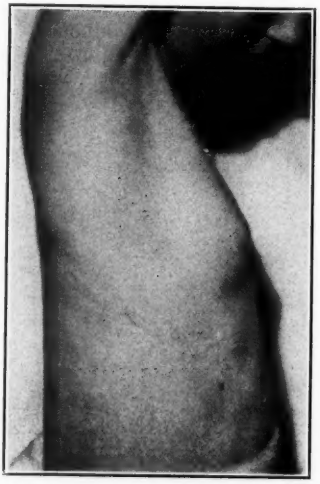

Fig. 18.—Case 2, M. B. Photograph taken thirteen months after operation. The patient gained 30 pounds in weight.

Dr. G. Y. Rusk submitted the following report: "Microscopic examination of sections fixed in Zenker's fluid shows a fine spongy structure, the somewhat irregularly distributed but numerous spaces being lined by a single layer of endothelium. Some of these spaces contain blood; others are empty, suggesting

the possibility of lymphatics rather than dilated blood capillaries. A few areas of necrosis occur. The parenchyma of the tumor consists essentially of spindle-shaped cells growing in strands of varying size, with round to oval nuclei containing one or more nucleoli and a varying amount of chromatic material. There is slight variation in the size of the nuclei. Nuclei in mitotic division are not seen. The cytoplasm in the more characteristic portions of the growth shows extremely fine linear striations. In the phosphotungstic acid hematoxylin stain the cytoplasm has more or less of a granular appearance. This is particularly true in the regions where the vascularity is the more marked. Interdigitating between the various individual cells there are extremely fine to coarse collagen fibers, as shown by the phosphotungstic acid hematoxylin as well as the Goldner stain. In some areas the parenchyma is relatively reduced, and the collagen becomes relatively quite obvious. Scattered in the tumor quite irregularly are groups of lymphocytes, at times more or less clumped, and in other places widely and sparsely disseminated. Diagnosis: Myoma of lung with lymphocytic infiltration, small areas of fibrosis and of necrosis; a richly vascular stroma is present.''

Specimens of this tumor were also sent to the same laboratories that had examined the first tumor, with the following reports: (1) malignant mesothelioma of the lung; (2) angiosarcoma, possibly leiomyosarcoma; (3) myoma, possibly rhabdomyoma; (4) rhabdomyoblastoma, definitely malignant; (5) myoma, definitely benign.

This patient was asked to come back a few days ago. She has gained 30 pounds in weight and is perfectly healthy and normal in every way. In x-ray pictures her chest appears to be normal (Figs. 16, 17, and 18).

SUMMARY

In summing up let me repeat that we have here two tumors, very similar in x-ray appearance, occurring in two young children with similar clinical findings—that is, fever and leucocytosis, with very little, if any, cough and practically no parenchymal involvement, and presenting histologically a very different type of tumor. Each one of these tumors has been diagnosed variously, all of which lends support to the idea that we are, as yet, somewhat in the dark as to the classification of many of the neoplasms which occur in the lung. I have no doubt that others have had similar cases. In reading some of the case reports, I have seen pictures that were somewhat similar, but the reports were so vague and unsatisfactory that they could not be included statistically.

It seems to me, therefore, that a Chest Tumor Registry would be invaluable in collecting material such as this for comparative study.

BENIGN CHONDROMAS OF THE RIBS

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INTRODUCTION

BENIGN tumors of the ribs are not so rare that they can be considered medical curiosities. However, they are not common enough for any author to have reported sufficient cases to draw definite conclusions from personal observations. As an illustration of their infrequency, Lemon, in 1919, reported the first chondroma of the ribs which had been seen at the Mayo Clinic. At that time the registration at the Mayo Clinic was 250,000 cases.

There have been excellent reports, which include collections of various types of tumors of the chest wall by Parham, Lund, Hedblom, Harrington, Heuer, Samson and Haight, and others. Most of these reports have also included malignant lesions of the chest wall, which are more common than benign tumors. Judging from the reports of these authors, there have been approximately sixty chondromas, nine fibromas, seven osteomas, and eleven benign giant cell tumors reported in the world literature.

Since these tumors are sufficiently rare that a series of personal cases has not been reported, I have attempted to collect a series of chondromas from the literature. In an effort to discover the origin, nature, and behavior of these lesions, I have combined the experiences of others. My review includes the cases of benign chondromas of the ribs which were proved by removal or biopsy and in which the report was sufficiently complete to be of value. It is, therefore, not meant to be a complete analysis of the world literature, but rather a review of a group of cases that seemed to be of value in drawing conclusions. I am adding one case of benign chondroma of the rib and one case which may be a myxomatous degeneration of a chondroma or a latent bone cyst, which is a form of osteitis fibrosa.

ETIOLOGY

The origin of chondromas is somewhat obscure. There are several theories which seem to have been given prominence in the literature. The theory of Müller (quoted by Ewing) that chondromas arise from cartilaginous fetal rests is substantiated by his findings of islands of superfluous cartilage in the periosteum of the ribs. Geschickter and Copeland feel that most of the chondromas and chondromyxomas rep-

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resent histogenetically supernumerary joint cartilage. The osteochondromas arise from the primitive connective tissue that forms the osseous ends of tendons. Virchow (quoted by Ewing) and others have shown that in rickets islands of cartilage occasionally remain standing entirely separate from the remainder of the cartilage, and they suggest rickets as an important factor in the formation of chondromas. Trauma has been frequently mentioned as a factor in the development of chondromas. Hedblom, Morton, Wakley, and Jeanneney and Chabe have reported very convincing cases to substantiate the relationship of trauma to chondroma.

Regarding the origin of osteoma or single exostosis, Hume (quoted by Roberts) considers the chondroma as being due to an abnormal stimulus affecting the center of the disk alone and interfering with the process of ossification; a single exostosis as being due to a stimulus affecting a localized area of the periphery. Keith and also Jansen (quoted by Roberts) group the two conditions together as being similar in nature.

PATHOLOGY

According to Geschickter and Copeland, chondroma, myxochondroma, osteochondroma, and osteoma are related to precartilaginous connective tissue, and these tumors represent different stages of the same pathologic process. The chondromyxosarcomas are malignant tumors of the same type. Histologically, there is no sharp dividing line between these various tumors, since the basic tissue comprising them, connective tissue, cartilage, and bone, are present in varying amounts in all of them. The chondromyxosarcomas are the malignant tumors of this series, the chondromas are potentially malignant, and osteochondromas are essentially benign.

The benign central chondromas represent a transition between osteochondromas and chondromyxosarcomas. In benign osteochondroma bone formation predominates, and the growth is primarily bone tissue with a thin cartilaginous cap. The myxomatous tissue is difficult to locate. In benign chondromas adult cartilage rather than bone predominates. In the strands of connective tissue that form the capsule, there is almost always myxoma and fetal cartilage.

It is possible for any of these tumors to undergo changes during its development and for tissue which was previously present in small amounts to assume increasing importance. Thus, a chondroma composed mostly of adult cartilage may ossify, and the osteoid tissue may increase in amount so that the tumor becomes an osseous chondroma simulating an osteochondroma. On the other hand, a chondroma may undergo myxomatous degeneration and become a myxochondroma. Still more important, the myxomatous tissue may assume greater importance and undergo malignant degeneration, thus developing into a chondromyxosarcoma.

TABLE I

REVIEW OF SOME OF THE REPORTED CASES OF BENIGN CHONDROMAS

AUTHOR	SEX AGE	DURATION OF TUMOR	HISTORY	LOCATION AND SIZE	TREATMENT	PATHOLOGIC DIAGNOSIS	RESULTS
Amburger, 1901	F 30	1 yr.	No trauma	3rd-6th ribs; child's head	Resection of 3rd-6th ribs and pleura	Chondroma	Death; empyema
Poulain, 1909	F 29	2 yr.	Trauma	8th-9th ribs; 30 × 39 × 45 cm.	Resection of 8th-9th ribs, diaphragm, and pleura	Fibromyxochondroma	Death; empyema
Lorain, 1912	M 58	8 yr.		6th-7th ribs	Resection of 6th-7th ribs and diaphragm	Chondroma	Death
Hesse, 1912	M 57	Months		10th rib; fist	Resection of 3 ribs	Myxochondroma	No recurrence after 6 months
Rigollot-Simonnot and Huguier, 1913	M 52	8 mo.		7th-8th ribs; 9 × 10 × 13 cm.	Resection of 7th-8th ribs, diaphragm, and pleura	Chondroma	Three operations for recurrence
Beccherle, 1914	F 44	1 yr.		4th-5th ribs; egg	Resection of 4th-5th ribs	Chondroma	Not stated
Lejars, 1914	F 42	3 yr.		11th rib; 6-8 inches	Resection of 11th rib, diaphragm, and pleura	Chondroma	Two recurrences
Geschickter and Copeland, 1908 1918 1913 1927	35 30 44 24			5th rib 3rd rib	Resection Resection Resection and x-ray Resection	Chondroma Chondroma Chondroma Chondroma	Recurred Immediate recovery Well for 8 years Immediate recovery
Lemon, 1919	M 61	25 yr.	Trauma and pain	1st rib	Biopsy	Chondroma	Recurrence 24 years after first removal
Hedblom, 1921	F 24	6 mo.	Tender	3rd-5th ribs	Resection of 3rd-5th ribs and breast amputation	Fibroma	Recovery
Hedblom, 1921	M 28	2 yr.	Trauma, tender	6th-7th ribs	Resection of 4th-7th ribs	Fibroma	Recurrence after 3 years. No second recurrence 1 year later
Turner and Mandel, 1921	F 46	8 yr.	Trauma and pain	3rd rib	Resection	Ossifying chondroma	Immediate recovery

Wakley, 1925		7 yr.	Trauma; no pain	6 × 7 in. large	Resection	Chondroma	Immediate recovery
Zinninger, 1930	F 26	4 yr.		2nd rib	Resection; pleura opened	Osteoma	Well for 1 year
Mole, 1928	M 37			Rib	Resection	Chondroma	Immediate recovery
Morton, 1930	M 63	3 yr.	Trauma	7th-8th ribs; 10 cm.	Resection	Osteochondroma	Well for 1 year
Hedblom, 1933	M 37	8 mo.	Trauma	2nd-3rd ribs; 8 cm.	Two-stage operation removing 2nd-4th ribs	Osteochondroma	Immediate recovery
Sorrel and Oberthur, 1933	M 11	2 yr.		4th-5th ribs; hen's egg	Partial removal	Chondroma	No increase after 1 year
Potvin, 1933	F 26	3 mo.	Pain	Lower ribs; fetal head	Removal of diaphragm and pleura	Chondroma	Immediate recovery
Folliasson and Blanchard, 1933	3½ mo.	3½ mo.		6th-7th ribs; 3 × 5 cm.	Resection	Chondroma	Immediate recovery
Auchincloss, 1934	M 23	7 yr.	No pain	8th-9th ribs; football	Two-stage resection	Osteochondroma	Death
Jitsuiki, 1934				2nd rib; fist	Resection	Chondroma	Immediate recovery
Moura and Rodrigues, 1935	M 21	Slow progress	No pain	1st rib	Resection and x-ray	Osteochondroma	Well for 1½ years
Jeanneney and Chabe, 1935	F 49	4 yr.	Trauma and pain	9th rib; fist	Resection; pleura opened	Osteoma	Immediate recovery
Klapp, 1936	F 28	Slow growing	Slight pain	1st rib; hen's egg	Resection	Fibro-osteoma	Immediate recovery
Sokolov, 1936	F 37	10 yr.	Pain	8th rib; fist	Resection of 7th-10th ribs; pleura resected	Chondroma	Immediate recovery
Gutierrez, 1937	M 24	1 mo.	No pain	3rd rib; 5 cm.	Resection of 3rd rib	Chondro-osteoma	Immediate recovery
Santy, 1937	M 38	4 yr.	No pain	3rd-4th ribs; orange	Resection 3rd-4th ribs and pleura	Chondroma	Immediate recovery

X-RAY EXAMINATION

Chondroma, if centrally situated, is shown in the roentgenogram as a well-defined translucent area surrounded by a bony capsule. If the chondroma is large, the cortex may be thinned out and expanded, and trabeculations may be present in the translucent area. Whenever the growth has perforated the surface of a bone or penetrated into the soft tissues, relics of the original cortical covering are seen as bony flakes of varying sizes on the periphery of the growth. The diagnosis of chondroma of the rib can usually be made from the location of the lesion and by the expansion of the bone. The absence of an infiltrating shadow in the periosteal zones argues against the presence of a malignant tumor.

RECURRENCE

Benign chondromas are very prone to recur. Hedblom noted a recurrence as late as six years after removal. There are several factors which seem to influence the tendency of benign chondromas to recur. Incomplete removal seems to stimulate the growth of the remaining tissue. It is, therefore, important that they be completely removed at the first operation. Hedblom has pointed out that chondromas removed early show much less tendency to recur than those of long duration and, therefore, advises removal as early as possible. Geschickter and Copeland made the observation that chondromas of the chest wall, when associated with chondromas of small bones of the hands, showed a greater tendency to recurrence after removal than those in which only the rib was involved. In the series which I have collected, five of the eleven cases which were followed more than one year recurred.

MALIGNANT DEGENERATION

The tendency for benign chondromas to undergo malignant degeneration makes their early recognition and removal extremely important. This tendency to malignant change has been emphasized by Hedblom, Graham, Roberts, and many others. Hedblom has been the most insistent that a large proportion of the cases of sarcoma start as nonmalignant tumors, particularly chondroma. He feels that, if the tumors can be recognized early before malignant changes have taken place and be completely removed, permanent cure can be obtained. He mentions that he has seen chondroma and osteochondroma present from five to twenty-five years before the onset of symptoms indicating malignant change.

Graham points out that many of these tumors which seem grossly benign have a tendency to recur after extirpation and even to form metastases. He considers that most of the cartilaginous tumors of the chest wall are really malignant. Boyd mentions sarcomatous de-

generation as the most important change to which chondromas are liable, but adds that it is always open to debate whether the tumor was not malignant from the beginning.

I have previously mentioned the pathology of chondroma and the relationship to the malignant chondromyxosarcoma. I have emphasized that the chondromas in the ribs are potentially malignant even though they may appear histologically benign. Geschickter and Copeland explain this malignant tendency of apparently benign chondromas of the ribs by the fact that the daughter lobules are remote from the sphere of influence of the cortical bone and hence are more prone to sarcomatous change.

There are some clinical evidences which may be interpreted as indicating malignant change. However, it is impossible to say clinically when a benign chondroma changes to a malignant tumor. The most reliable clinical changes are sudden increase in size of a previously quiescent tumor or the sudden development of pain. Although pain is an indication of beginning malignant change, it is not reliable, as some benign chondromas may be painful.

Hedblom gives some indication as to the proportion of benign chondromas which undergo malignant changes. In his report of 1921 he points out that, while 62.4 per cent of his cases were sarcoma, more than 8 per cent were combinations of chondroma and sarcoma and probably originated as chondromas.

TREATMENT

The treatment of chondromas resolves itself largely into a question of the indications for removal and the technical problems involved. Most authors feel that the removal should be early and complete because of the danger of malignant change. Hedblom points out that operative trauma seems to stimulate any residual tissue to activity and that it is therefore important that residual tissue be entirely removed together with wide margins of healthy tissue. Geschickter and Copeland advise removal followed by radium therapy. Moura and Rodrigues report a case in which roentgen therapy following removal seemed to be effective. However, most authors, including Samson and Haight, feel that chondromas usually do not respond to irradiation.

The technical problem of complete removal of chondromas of the ribs is often difficult and serious. Harrington feels that tumors which involve the thoracic wall often present greater technical difficulties than those which are entirely contained within the thoracic cavity. In many cases it is necessary to remove large sections of the pleura or diaphragm, resulting in difficult problems in repair of the defect. In some cases it has been necessary to remove the tumor in two stages in order to lessen the shock to the patient. Santy,

Sokolov, Auchincloss, and Potvin have recently reported cases which presented particularly difficult technical problems. In ten of the cases I have recorded, it was necessary to open or resect part of the pleura in order to remove the tumor completely. Most authors plan their surgical approach directly over the tumor. In two females the breast was amputated in order to facilitate the exposure of the tumor. While in some cases it may be necessary to amputate a woman's breast, I feel that in the smaller tumors the approach I have used which allows retraction of the breast is more satisfactory.

CASE REPORTS

CASE 1.—The patient was a girl aged 17 years. She gave a history of having had a "lump in her left breast" for about one year. She said that it had been increasing in size during the preceding two months. There was no history of trauma, and she did not complain of pain, dyspnea, or tachycardia. With the exception of a history of hay fever, her past history was essentially negative.

Fig. 1.—Case 1. Roentgenogram of the ribs showing osseous chondroma. The tumor expands the bone but leaves the periosteum intact and does not infiltrate the surrounding tissue.

The patient was a well-developed and well-nourished young girl. On examination a hard, nodular, fixed tumor about 3 cm. in diameter was felt behind the left breast almost directly behind the nipple. It apparently arose from the fourth rib. The tumor was not tender to palpation. The heart and lungs were normal on examination. Her temperature was 98.2° F., pulse 86, and blood pressure 110/70. The blood and urine examinations showed no abnormality. Roentgenograms of the chest revealed a multilocular tumor approximately 5 cm. in diameter and involving the anterior end of the fourth rib on the left side (Fig. 1).

The operation was done under cyclopropane. The patient was placed on her back with a small pillow under the left shoulder. The left arm was held by an assistant. The incision was the type of incision used by Haight and also by

Alexander for anterior thoracoplasty. The incision started from 2 to 3 cm. mesial to the axillary fold and continued as a semicircular incision lateral to the breast and as far medial as the midclavicular line at its lower end. After carrying the incision through the skin and axillary fascia, the pectoralis major muscle was separated from the serratus anterior muscle and chest wall and retracted medially and anteriorly together with the breast. The lateral fibers of the pectoralis major muscle were divided from the chest wall to facilitate the exposure. The origins of the pectoralis minor muscle were then freed from the ribs and retracted. The incision, carried out in this way, gave adequate exposure of the chest wall from the second to the fifth ribs and as far medially as the sternum.

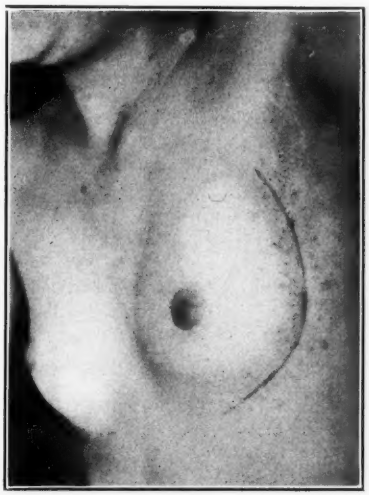

Fig. 2.

Fig. 3.

Fig. 2.—Case 1. Photograph showing the scar remaining after the removal of the chondroma of the fourth rib.

Fig. 3.—Case 1. Roentgenogram of the ribs fourteen months after removal of the chondroma of the fourth rib. There is no evidence of recurrence.

The tumor was found to have replaced the distal end of the fourth rib and adjoining cartilage. It was firm and nodular. The fourth rib was freed for about 5 cm. lateral to the tumor and divided at that point. The intercostal bundles were then carefully separated from the tumor, and a line of cleavage was developed between the tumor and the parietal pleura. The tumor was removed by dividing the cartilage of the fourth rib at the sternum and removing the lateral border of the sternum with a rongeur. The parietal pleura was not opened, and while it was closely adherent to the tumor, it did not seem to be involved. The free margin of the pectoralis minor muscle was sutured to the edges of the defect left by removal of the tumor, and the wound was closed with interrupted catgut and dermal sutures without drainage.

The patient's postoperative convalescence was uneventful except for a nonproductive cough which lasted about two weeks and then disappeared. Her temperature rose as high as 100.6° F., but returned to normal on the fifth day. She was discharged from the hospital at the end of one week. The wound healed by primary union without subsequent drainage (Fig. 2). The patient has been carefully followed for more than one year. Roentgenograms taken at intervals of six months show no evidence of recurrence (Fig. 3).

Examination of the tissue showed a tumor encircling a rib and its costochondral junction. The tumor measured 5 cm. by 4 cm. It was of cartilaginous consistency with harder nodular areas (Fig. 4). Microscopic examination showed the tumor to be made up chiefly of cartilage (Fig. 5). There were a few small areas of bone and an occasional small area of fibrous tissue. There was no histologic evidence of malignancy.

Fig. 4.—Case 1. Photograph showing the gross specimen of tumor which is cartilaginous with nodular bony areas.

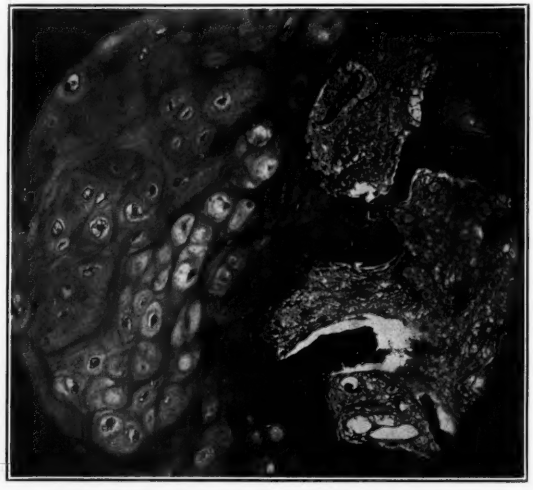

Fig. 5.—Case 1. Photomicrograph of section of tumor. The tissue is primarily adult cartilage and bone.

CASE 2.—This case is reported through the courtesy of Dr. J. R. Plank of Denver. The patient, a male aged 41 years, was first seen in September, 1935, when he gave a history of periodic pain in the right upper quadrant of the abdomen for a period of six years. During this time he had been treated for chronic gall bladder disease without relief. For the preceding six months the pain had been more continuous and more severe. There was no history of

Fig. 6.—Case 2. Roentgenogram of ribs. The tumor expands the rib, but the periosteum is intact.

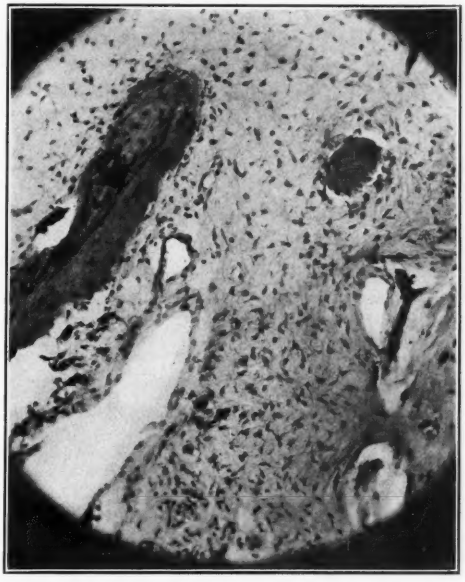

Fig. 7.—Case 2. Photomicrograph of section of tumor. The tissue is loose, mature, and myxomatous connective tissue with bone spicules.

trauma. Roentgenograms taken to demonstrate the gall bladder showed it to be functioning normally, but revealed an expansive lesion of decreased density in the sixth rib, about 10 cm. long, and extending down to within about 4 cm. of the costochondral junction. The x-ray diagnosis was probable chondroma or latent bone cyst (Fig. 6).

The examination was essentially negative except for a small firm tumor on the sixth rib, which was firmly fixed but not attached to the skin or overlying tissues. The urine and blood were normal, as were also the temperature, pulse, respirations, and blood pressure.

The tumor was removed through a transverse incision over the rib. The pleura was not opened in removing the tumor. About 2 cm. of rib was resected beyond the diseased area at either end. The wound was closed without drainage. The patient's postoperative course was uneventful. He has had no evidence of recurrence during the three and one-half years since his operation. His former pain disappeared immediately after his operation and has not recurred.

The pathologic diagnosis in this case is somewhat obscure. The microscopic examination of the tissue shows marked periosseous thickening, while the center portion is filled with myxomatous connective tissue and mature fibrous tissue. This fibrous tissue is extremely scarce in cellular elements. There is no evidence of malignancy. The diagnosis lies somewhere between a myxomatous degeneration of a chondroma and a latent bone cyst. The lack of density of the fibrous tissue is against the diagnosis of a pure fibroma.

CONCLUSIONS

From a review of the experiences of others combined with my observations in the two cases which I have presented, I have gained a few impressions regarding the origin, nature, and behavior of benign chondromas of the ribs.

It is my impression that these tumors start insidiously and are generally of long duration. For the most part, the tumor is accidentally discovered by either the patient or the doctor. In other cases, the lesion is incidentally noticed in a roentgenogram of the chest. Pain has been mentioned often as an indication that a chondroma is undergoing malignant change. Since pain may also occur in benign chondromas, it is not an accurate diagnostic criterion of malignant change.

Regarding the nature of benign chondromas and osteochondromas, I get the impression of much duplication and confusion in the literature. The words osteoma, exostosis, fibroma, myxochondroma, etc., have been loosely used. It would seem that the benign osteogenic tumors of the ribs could all be classed as either chondromas or osteochondromas. All of these tumors contain cartilage, bone, osseous tissue, and fibrous connective tissue. The osteochondromas or exostoses arise as bony tumors and are surrounded by a cartilaginous cap. The chondromas contain adult cartilage primarily, but may ossify to form osseous chondromas or may undergo myxomatous degeneration and be called myxochondromas.

The literature is somewhat complicated and obscure regarding the origin of chondromas. Three theories seem to be prevalent: these theories are that chondromas originate from fetal rests, from islands

of cartilage resulting from rickets, or as a result of trauma. The osteochondromas seem to arise from the tendinous attachments, and the chondromas arise from joint cartilage. The other etiological factors may be of significance. Regarding trauma, there have been convincing cases reported which were definitely traced to trauma. However, viewing the series as a whole, a history of trauma is far from constant. The opinions in the literature seem to be almost unanimous that chondromas, even though they appear histologically benign, are prone to recur and to become malignant. They should, therefore, be considered as potentially malignant tumors.

Finally, while a few authors have advised irradiation, the overwhelming majority of opinion is in favor of early and complete removal. The complete removal is important because of the danger of recurrence even though the tumors are histologically benign. Early and complete removal is even more important because of the danger of malignant changes which may take place in these tumors at any time in the course of their development. Each case presents an individual surgical problem. To judge from the reports, the surgical problem may be extremely difficult and require a great deal of ingenuity. The best approach for the removal of these tumors is the one which is the least mutilating and still compatible with thorough ablation of the tumor.

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(See discussion on page 159.)

PRIMARY TUMORS OF RIBS

Report of Eight Cases and a Method of Repair of the Defect in the Chest Wall That Follows Their Removal

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METASTATIC tumors of the ribs are very common; primary tumors, on the contrary, would appear to be relatively rare. As would be expected, all types of bone and cartilage growth that affect the remainder of the bony skeleton are found in the ribs. Because of their anatomic location, they are likely to come under the care of the thoracic surgeon. As they occur infrequently, reliable information regarding the best methods of treatment and prognosis is likely to be obtained only through the publication of small groups of cases.

Samson and Haight[1] were able to collect only nine cases of giant cell tumors from the literature in 1935. To these they added one case of their own. The tumor was excised, and at the time of the report, ten months later, there was no evidence of recurrence. Hilt[2] reported one case in 1937. The lesion was treated by radiation and was apparently cured at the end of two years. Samson and Haight expressed the opinion that, if one could be certain of the diagnosis, radiation would be the best form of treatment. It is, I should think, not possible to distinguish by x-ray alone a giant cell tumor from a single myeloma or even from a single metastatic lesion. It is usually possible to exclude the secondary tumors by aspiration biopsy, but the primary conditions sometimes present considerable histologic difficulty. Since excision is usually relatively simple, it would appear to be the procedure of choice.

Single myelomas of ribs have, so far as I have been able to determine, not been reported previously. Two have come under our care. In the x-ray they present the typical appearance with which we are all familiar in the more common multiple form. Cutler, Buschke, and Cantril[3] reported twelve single myelomas of bone which they regarded as having been proved, either by autopsy or x-ray examination, to be single. It would seem that neither negative x-ray nor autopsy findings can be accepted as positive evidence of the absence of other small foci. Two of the twelve patients, however, were alive for sufficiently long periods, four and eight years, respectively, from the time of operation, without showing further areas of disease, to make it reasonably certain that the lesion was really

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single. It would appear, therefore, that there is some justification for the excision of what seems to be a single myeloma on the faint chance that it might be the only lesion. There is, of course, further justification in that, apart from biopsy, it is usually impossible to be certain of the nature of the tumor before it is excised. The above writers[3] state that, although Bence-Jones proteinuria may be found in a solitary lesion, it is not usually present in the early stages of the disease. In the only one of our cases in which the test was done, it was negative.

Chondromas and osteochondromas probably arise, as in the long bones, from cartilage rests and would be properly regarded as enchondromas or ecchondromas. Gerster's case is of interest in this connection in that the rib tumor developed in a man who was known to have had an exostosis of the humerus for forty years and of the tibia for forty-two years. The majority would appear to have arisen at or near the costochondral junction.

Gerster,[4] in 1919, reported a massive chondroma of the ninth, tenth, eleventh, and twelfth ribs in a man 60 years old. It was said to have developed over a period of nine months and to have followed trauma. The patient made a good recovery from operation and was well seven and one-half months later. The rapid development of the tumor and its great size would suggest that it was possibly a chondrosarcoma. Wakeley,[5] in 1925, reported a chondroma of the fourth rib 6 to 7 inches in diameter and attached in the region of the axilla by a pedicle only ¾ inch in diameter. It occurred in a man 42 years of age, had been known to be present for three years, and was supposed to have followed a local injury received seven years previously. It was removed successfully.

One has nothing on which to base an opinion regarding the tendency of these benign lesions to undergo malignant changes. In Case 4 the tumor showed sufficient cellular activity to make one feel that, had it not been removed, it might have undergone such changes.

The literature on the subject of cartilage and bone sarcoma of ribs is not very illuminating. About one-half dozen individual case reports appear. Of the patients who were followed for any length of time, most developed early metastases. One,[11] reported free from metastases, would appear from the x-ray and microscopic description to have been a case of giant cell tumor. Hedblom,[12] in an extensive paper in 1921, collected 213 cases of tumors of the bony chest wall, but, as inflammatory lesions as well as many types of secondary tumors were included, the collection is not very helpful.

I have found reports in the literature of only eight cases of Ewing's tumor of the ribs. Herbert[14] reported two cases in 1935. The first patient, a boy 10 years old, died in four months of a complicating infection; the second, a male 20 years old, was dying at the time of

the report five months after the onset. The tumor had been excised locally two and one-half months after it was noticed. Blalock, in discussion, reported two other cases. One patient, a male 20 years old, had had an extensive tumor involving three ribs removed and showed no evidence of metastases three years later. The second, a male 19 years old, was alive with metastases at the end of two years. Bergstrand[13] reported four cases in 1936. They occurred in children aged 15, 10, 10, and 14 years. One patient treated by extirpation and x-ray was alive at the end of five and one-half years, although metastases had occurred in the lung two years after operation and had disappeared under x-ray treatment. One was alive two years after extirpation of the tumor but had multiple pulmonary metastases. In one, the outcome was not given, and in the last, the patient was alive two years after the onset, having been improved greatly by x-ray treatment. These reported cases probably do not really represent the frequency of the disease, but it is interesting that in their book on tumors of bone Geschickter and Copeland described sixty-five Ewing's tumors, only one of which occurred in the ribs.

The defect in the chest wall that results from the extensive resection of one or more ribs along with periosteum and attached muscles often constitutes a real disability, particularly in an individual compelled to earn a living by manual labor. The method of repairing this defect, described in the report of Case 4, proved very satisfactory in the single case in which it has been used. It would appear to be applicable, with minor variations, to any part of the wall. The placing of a layer of fascia between the graft and the underlying lung is probably unnecessary, and since it adds considerably to the operation and increases the tendency to bleeding and subsequent exudation of serum, is perhaps unwise.

The series of eight cases that have come under our observation in a period of approximately twenty years is made up of one giant cell tumor, two so-called single myelomas, one chondroma, one osteochondroma, one chondrosarcoma, one osteogenic sarcoma, and one which was regarded from the x-ray appearance as a typical osteogenic sarcoma, but which, because of its response to radiation, may be a Ewing's tumor.

CASE REPORTS

CASE 1. *Giant Cell Tumor.*—A man, 49 years old, had complained of pain along the right costal margin for ten months. Clinical examination of the chest was negative, but the screen revealed a tumor of the seventh rib in the postaxillary line (Fig. 1). There was no deterioration in general health. X-ray examination showed a fusiform enlargement and area of destruction of the seventh rib about 3 inches in length. The hemoglobin was 83 per cent, white blood count, 10,800, and Bence-Jones protein test, negative. At operation Sept. 19, 1936, the seventh rib, along with the adjacent intercostal muscles and underlying pleura, was removed from the vertebra to the anterior axillary line. Recovery was uneventful. In the

gross the specimen consisted of a soft grayish red mass, expanding and largely destroying the rib over an area 8.5 cm. long. The cut surface was vascular and dark red brown. The central part appeared to be broken down and was enclosed by a shell of a maximum thickness of 2 mm., the outer part of which consisted of periosteum with a very thin incomplete layer of bone beneath it (Fig. 2). Microscopically the wall of the cystic space was seen to be formed in large part by fibroblastic tissue (Fig. 3) which suggested an inflammatory lesion. Other areas presented what seemed to be definite evidence of tumor formation, with here and there a few giant cells. Under the thickened periosteum was a thin layer of new bone. A diagnosis of giant cell tumor was made.

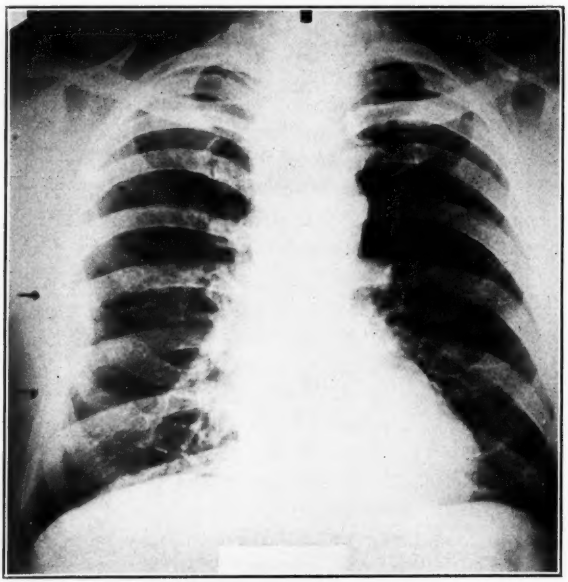

Fig. 1.—Case 1. Tumor of seventh rib indicated by arrows.

The patient was readmitted on June 14, 1938, having remained well until three weeks previously, since which time he had suffered from cough, hemoptysis, and a sense of constriction and soreness in the lower left chest. There had been no change in general health and no loss of weight. Clinical examination revealed what was interpreted as a partial collapse of the left lower lobe and, on one occasion, a friction rub. X-ray examination showed thickening of the pleura over the lower left chest, collapse of the lower lobe and probably a small amount of fluid in the pleural cavity, as well as a shadow at the hilum suggestive of carcinoma of the bronchus. Bronchoscopic examinations on June 20 and June 30 showed a considerable amount of blood and mucus in the left lower lobe bronchus, but no tumor could be seen. Exploratory thoracotomy was not thought justifiable because of the bony defect in the other chest wall, and the patient was discharged for further observation by his physician.

The condition progressed. Bronchoscopic examination was repeated on Aug. 16, 1938. There was much old blood in the bronchial tree, but fresh blood came only from the left lower lobe. An exploratory thoracotomy was carried out on Aug. 18, 1938. An inoperable condition was found. It was thought to be a carcinoma of the

bronchus with secondary inflammatory changes. Unfortunately, a small nodule which was removed from the pleural surface in the expectation that examination of it would clarify the diagnosis proved to be chronic inflammatory in origin, and no tumor cells could be found in the pleural fluid.

The patient died some eight months later. No autopsy could be obtained. The cause of death is only presumed to have been carcinoma of the bronchus.

The subsequent history of this case throws doubt upon the accuracy of the pathologic diagnosis of the original tumor. It has fortunately been preserved in the museum. Multiple sections have been made from this specimen, and the pathologist persists in the diagnosis of benign giant cell tumor. It is certainly not a secondary tumor. No other lesion of bone developed.

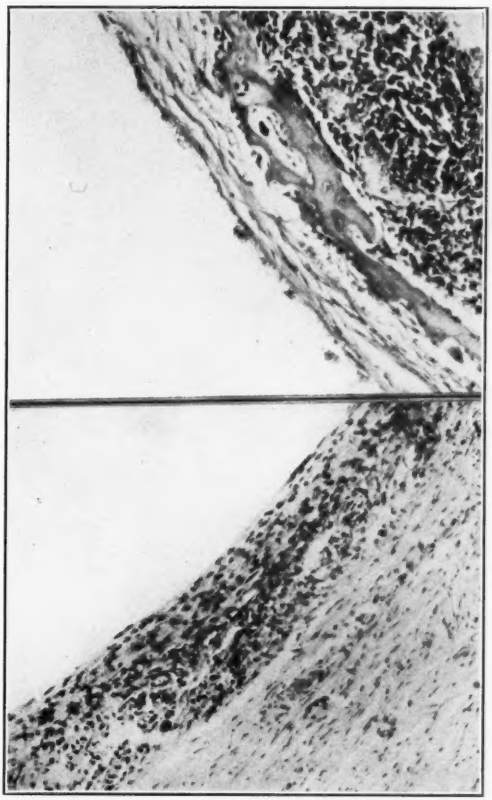

Fig. 2.

Fig. 3.

Fig. 2.—Case 1. Actively growing area with subperiosteal new bone formation on surface.

Fig. 3.—Case 1. Fibrous character of another part of the wall.

CASE 2. *Myeloma.*—A woman, 63 years old, had consulted her physician frequently during the previous six to seven years because of pain in the region of the right shoulder. It was considered, apparently without any real evidence, to be due to a mild pleurisy. In the past year she had had a persistent nonproductive cough and, for six months, had noted an increasing pallor. X-ray examination of the chest, made six weeks before admission, showed an expansile tumor of the second

rib just lateral to the cartilage but with no change in the underlying lung or pleura (Fig. 4). Clinically she was well nourished, somewhat pale, but presented no abnormality apart from a marked sclerosis of the peripheral vessels and a slight thickening below the left clavicle. This swelling appeared to pulsate. X-ray films of most of the remainder of the skeleton showed no other areas of destruction. No other primary tumor from which a metastasis might have arisen could be found. The hemoglobin was 75 per cent, white blood count, 5,200, and the differential smear was not abnormal. The Bence-Jones protein test was negative.

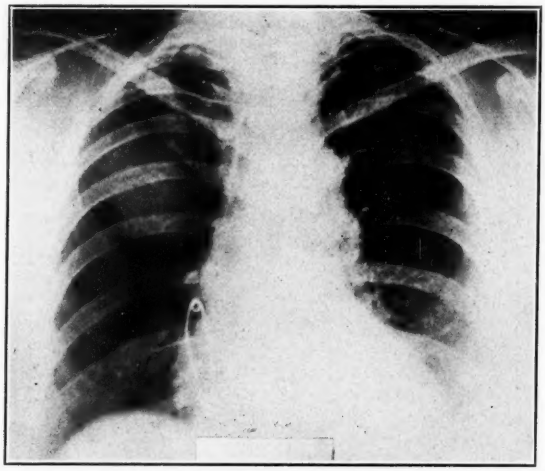

Fig. 4.—Case 2. Single myeloma of second right rib.

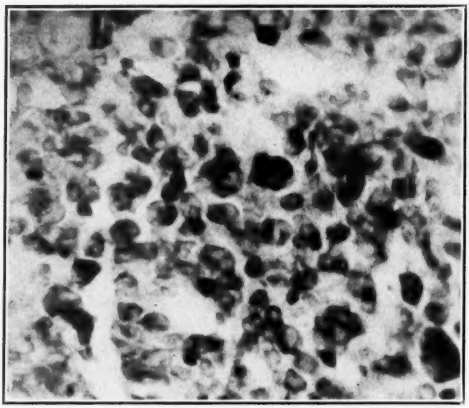

Fig. 5.—Case 2. Myeloma.

At operation on June 17, 1930, the soft tissues of the anterior chest wall were turned upward and mesially from an axillary incision. The tumor and the adjoining rib and cartilage, the attached intercostal muscles, and the underlying pleura were removed en masse. The growth extended from the middle of the

second costal cartilage to midaxilla, following the line of the second rib. Recovery was uneventful.

The gross specimen consisted of a fusiform mass 8 by 4.5 by 2 cm. It was soft, dark red, and appeared to be a mass of hemorrhagic material enclosed by a fibrous capsule. Microscopic examination disclosed a very cellular tumor, the cells of which varied greatly in size and shape, some being small and round, others long and spheroidal (Fig. 5). Many of the smaller cells possessed dark-staining eccentric nuclei and were somewhat similar to plasma cells. The larger cells presented considerable variation in the amount and distribution of nuclear content. It was regarded as a single myeloma.

Fig. 6.—Case 2. Lesions in mandible and femur eighteen months after excision of rib tumor.

The patient remained quite well until December, 1931 (18 months) when an aching pain developed in the left jaw and, shortly afterward, swelling. In January, 1932, she noticed pain above the right knee. X-ray films made in February, 1932, showed the typical expansile lesion of myeloma in both these bones (Fig. 6). A spontaneous fracture of the femur occurred later. She died nine months later. Unfortunately the Bence-Jones test was not repeated.

CASE 3. *Myeloma.*—A man, 61 years old, had had a fracture of the eighth rib on the right side three years previously. X-ray pictures made at that time showed a fracture of the eighth rib and a normal sixth rib. There had been pain in that region from time to time since the injury, and he had been treated by adhesive strapping. For six months the pain had been more severe, and one week before admission he had noticed a lump. Examination revealed a mass about 5 by 9 cm.

along the sixth rib in the right axilla. It was elastic to feel, and there was an impulse on coughing. X-ray examination showed no other bony abnormality. The Bence-Jones test was not done. X-ray of the chest showed an area of destruction of the sixth rib, beginning about 2 cm. lateral to the costochondral junction and extending along the rib for about 9 cm. The appearance presented was thought to be that of an expansile tumor which had ruptured through the cortex and now lay partly in the soft tissues.

At operation, Jan. 15, 1932, the adjacent portions of the fifth and seventh ribs were first resected and the tumor then removed along with the whole of the intercostal bundle on either side and the underlying pleura. The diaphragm was used to close the defect. He died of pneumonia on the third postoperative day. No autopsy was obtained.

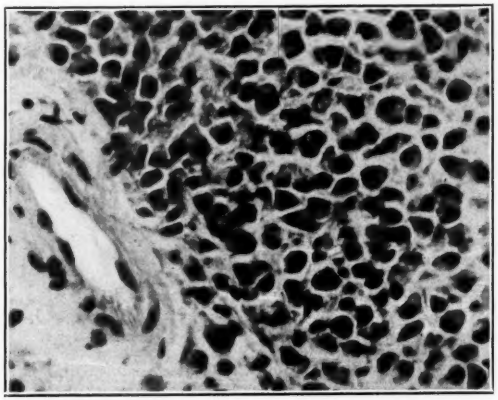

Fig. 7.—Case 3. Myeloma.

Case 4. *Chondroma.*—A man, 30 years old, was found to have a tumor of the right chest wall in the course of routine screen examinations of the chests of a group of factory employees (Fig 8). There were no associated symptoms. The right upper chest was definitely flat, and the retraction involved especially the third rib and cartilage. There was a hard, slightly irregular, fusiform swelling of this rib just beneath the axillary border of the pectoralis major. X-ray examination revealed a tumor of the third rib about 3 inches in diameter and extending laterally from the costochondral junction. It had an irregular mottled appearance. At operation Nov. 2, 1938, an incision was made along the pectoral border and extended medially toward the sternum. The pectoralis major was divided below and reflected upward and inward. The tumor with about 1 inch of rib lateral to it, a similar length of cartilage medial to it, a small portion of attached muscles, and the underlying pleura were removed. There was only one small bandlike adhesion to the underlying visceral pleura, despite the fact that the mass had formed a definite depression in the lung. The second and fourth ribs and cartilages were separated more than usual because of the tumor, and it seemed that a considerable defect in the chest wall would result unless some sort of plastic repair could be accomplished. Fig. 9 shows the manner in which this was carried out. The fourth rib and cartilage were split with a motor saw from near the sternum to beyond the point of division of the third rib laterally, leaving the remaining portions of intercostal muscles and periosteum attached to it. The upper half was divided medially, carried up and fastened with a single chromic

catgut suture into a seat prepared by removing, subperichondrially, the small remaining portion of the cartilage of the third rib. In doing this, a greenstick fracture was produced at the outer end. The fascia and a thin sheet of muscle

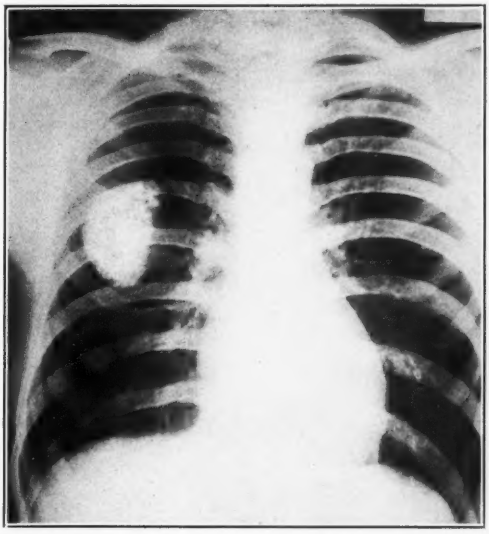

Fig. 8.—Case 4. Chondroma. Density of shadow due to calcium and not true bone.

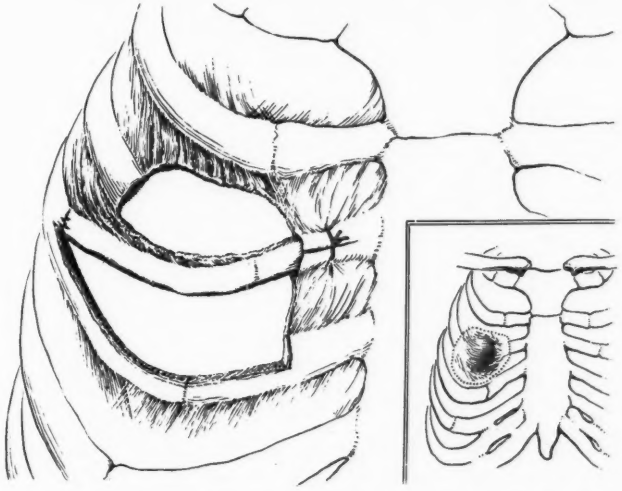

Fig. 9.—Case 4. Diagrammatic representation of tumor and of method of repair of chest wall defect.

were dissected from the pectoralis major muscle and carried beneath the graft to provide a smooth surface between it and the underlying lung. The remaining portion of the pectoralis major was sutured securely into position with

chromic catgut, and finally, the subcutaneous tissues and skin were closed. Convalescence was somewhat stormy because of the occurrence of a massive pleural effusion and pulmonary collapse. The patient is now well and has a chest wall of normal stability.

In the gross, the tumor was a hard mass of bone and cartilage 11.8 by 7 by 5 cm. Microscopically it was seen to be made up of large islands of cartilage cells lying in clear spaces surrounded by blue-staining matrix (Fig. 10). Many areas had undergone calcification, but true bone formation was not seen. Cystlike spaces lined by cartilage cells were distributed irregularly throughout the tumor. The surface was covered by a layer of dense fibrous connective tissue. It was regarded as a chondroma with calcareous degeneration.

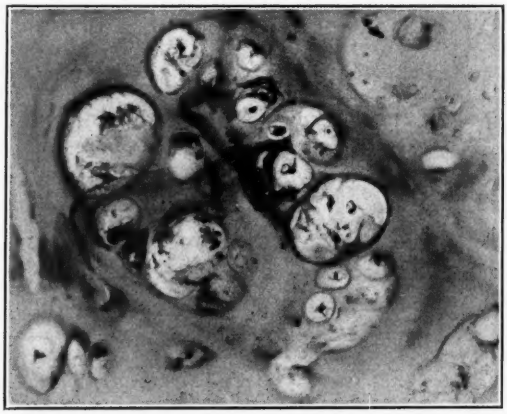

Fig. 10.—Case 4. Island of cartilage cells with surrounding matrix.

CASE 5. *Osteochondroma.*—A man, 40 years of age, had complained of a continuous dull ache or pain in the left chest since the spring of 1916. A lump was noticed in the summer of 1917 over the lower left chest. It had enlarged slowly. There was a rounded swelling extending posteriorly from the costochondral junction of the ninth and tenth ribs and projecting about 1 inch from the level of the chest wall. X-ray examination showed a bony tumor, markedly irregular in outline and appearing to encroach upon the abdominal cavity through the diaphragm. At operation on Aug. 16, 1918 the growth was found to be arising from the ninth rib in the region of the costochondral junction. It was removed along with the neighboring portions of rib and cartilage and the adjacent soft tissue and pleura. The diaphragm was found to have been displaced but not perforated. Recovery was uneventful. In the gross the specimen consisted of a mass of cartilage and bone the size of an orange. Histologically it was a benign osteochondroma. The patient is still alive and well.

CASE 6. *Osteogenic Sarcoma (?).*—A man, 36 years old, was admitted on Oct. 19, 1937. He complained that for the past five years the right arm and shoulder region "went to sleep" when he was writing at a desk and that during the same period numbness and tingling had involved the whole circumference of the right arm on many occasions. These attacks did not appear to have increased in severity or frequency. On three occasions during the past six months he had suffered from shooting pain in the right shoulder followed by a dull ache for two to three days. He had lost 10 pounds in the past ten weeks. The right arm presented no ab-

normality. There was a slight visible and palpable fullness in the right supraclavicular fossa. X-ray examination showed a tumor about 2 by 3 inches arising from the second rib in its posterior half (Fig. 11). The normal contour of the

Fig. 11.—Case 6. Tumor of second rib shown Jan. 24, 1938, before radiation.

Fig. 12.—Case 6. After radiation, Dec. 8, 1938.

rib was destroyed, and the major portion of the tumor was made up of radiating spicules of new bone. The picture was regarded as characteristic of osteogenic sarcoma. Roentgenograms of the chest and general physical examination revealed

no evidence of metastases. Three extensive courses of x-ray therapy were given, using a 400 kv. machine. The tumor has become only slightly smaller but has undergone marked calcification. The patient rather rapidly regained the weight that he had lost and is at present working and apparently well. The response that this tumor has shown to x-ray therapy would seem to make the original diagnosis of osteogenic sarcoma scarcely tenable and would suggest that it is more likely a Ewing's tumor.

Fig. 13.—Case 7. Osteogenic sarcoma of eleventh rib.

CASE 7. *Osteogenic Sarcoma.*—A man, 54 years of age, was admitted July 21, 1938. One week previously his son had noticed a deformity of the lower chest. There were no local symptoms, and the general health had remained good. There was an elongated swelling of the eleventh right rib which extended forward for about 7 inches from a point near the spine and was of a maximum width of about 2½ inches. It was firm, somewhat irregular in outline, and not tender. X-ray examination showed replacement of the eleventh rib by a circumscribed bony tumor which had a vacuolated appearance suggestive of either a chondroma or chondrosarcoma (Fig. 13). At operation July 22, 1938, an ample incision was made in the long axis of the tumor. The tenth rib was first resected subperiosteally to give access, and the involved rib was then removed from anterior to the tumor to and including the head of the rib, along with the attached intercostal muscles and underlying pleura. The muscles were closed over the defect. Postoperative recovery was uneventful, and at present there is no clinical or x-ray evidence of recurrence.

In the gross, the specimen was bony hard. The attached muscle tissue was intimately adherent to it. Microscopically the mass was made up of dense sheets of cells with long spindle-shaped nuclei and varying amounts of cytoplasm, growing

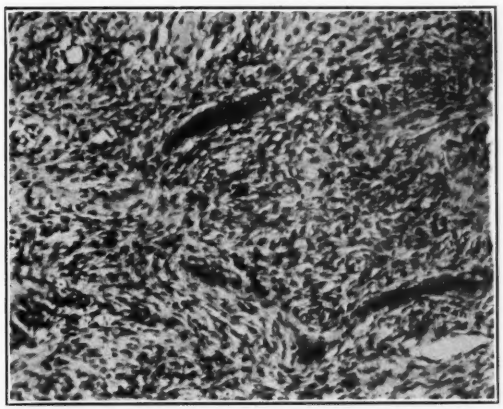

Fig. 14.—Case 7. Osteogenic sarcoma.

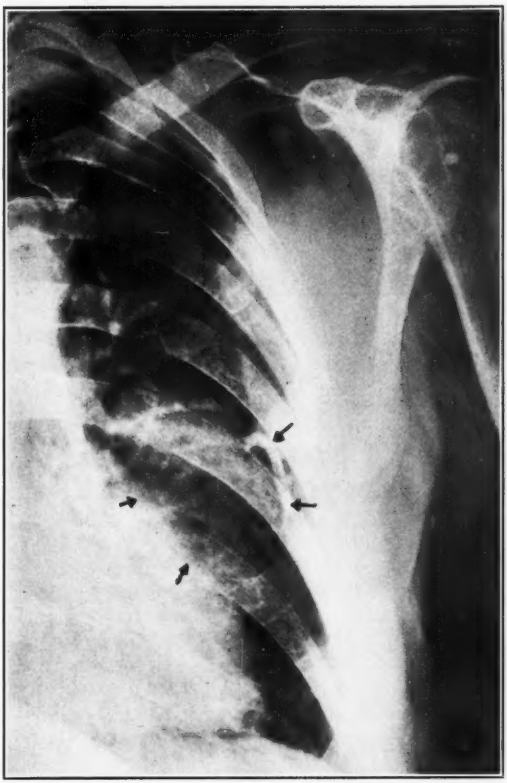

Fig. 15.—Case 8. Chondrosarcoma. Outline of indistinct shadow indicated by arrows.

in very irregular fashion (Fig. 14). Distributed throughout these cells were many multinucleated bone cells about which there were deposits of new bone. It was regarded as an osteogenic sarcoma.

CASE 8. *Chondrosarcoma.*—A man, 63 years old, noticed a swelling of the left chest wall in October, 1937. The mass was not painful and was noticed by chance. X-ray films made shortly after showed a tumor about 10 by 12 cm., arising from the region of the costochondral junction of the third rib on the left side. The shadow was very indistinct because of an almost complete absence of calcium (Fig. 15).

Examination revealed a flat, firm swelling about 2 inches in diameter arising from the third left rib lateral to the costochondral junction.

What appeared to be the whole growth was removed by his surgeon on Nov. 16, 1937.

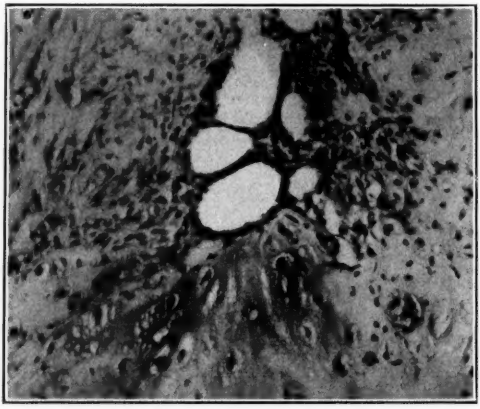

Fig. 16.—Case 8. Chondrosarcoma.

The specimen consisted of a mass 7 by 6 by 5 cm., which appeared to surround the rib. It was moderately firm, pinkish, and somewhat lobulated. On section it was gelatinous in appearance and very friable. Microscopically the tumor was seen to be made up of large masses of cartilage cells. Near the periphery it was very cellular, and the cells were less differentiated in character and were invading between the fibers of attached muscle. There were a few areas of myxomatous degeneration (Fig. 16).

The patient received one series of 3,000 R. postoperative radiation but failed to report for further treatment. He returned Nov. 3, 1938, with numerous secondary masses in the region of the incision. Subsequent radiation has failed to control these recurrences.

SUMMARY

A brief review of the available literature on rib tumors has been given. Eight new cases have been added. The value of individual case reports would often be much greater if the patients had been followed for a longer period of time. One would suggest that the establishment of such a follow-up by this society might be worth while.

I should like to express my thanks to Dr. N. S. Shenstone for the privilege of including his cases in this report and to Dr. William Robinson, surgical pathologist to the Toronto General Hospital, for the pathologic descriptions.

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DISCUSSION ON "BENIGN CHONDROMAS OF THE RIBS," BY DR. FRED R. HARPER*; AND "PRIMARY TUMORS OF RIBS," BY DR. ROBERT M. JANES

DR. FRANK B. BERRY, New York, N. Y.—These two papers have been extremely interesting to me because we have wondered why we have not seen more tumors of the ribs in a rather larger service in a municipal hospital in New York City. As I have listened to the papers, the explanation has come to my mind that, particularly in the large cities, we have hospitals with charity services for tumors, and I think most of these cases are going to those hospitals. That has been further borne out from the fact that I have seen, within the past two years, two Ewing's tumors, postoperatively, at the Memorial Hospital in New York City. Dr. Coley, with whom I saw these patients, told me he had had one or two others from whom he had successfully removed such tumors. I saw these two patients because, following the extirpation of the tumors, they developed empyema, and I was called in then to help out with the empyema. One of these patients was a medical student who was operated upon late in the summer last year. He had had a very radical operation with the removal of four ribs. In the course of his convalescence he developed empyema. His lung was finally re-expanded, and he went back to medical school. This winter he returned to New York with an intractable pain in the sciatic nerve, which was relieved temporarily by x-ray therapy. Although nothing could be seen by x-ray, I think Dr. Coley believes he is already having a recurrence.

He told me of another of his patients he had had within the past year who was still well. About seven years ago I removed one of these tumors of a rib, diagnosed by Dr. Knox of St. Luke's as an osteogenic sarcoma, from the lateral

*See page 132 for article by Harper.

chest wall, and the girl is still well. That brings up a criticism of some of our college health departments which I think we can all watch; that tumor was picked up by a routine x-ray film when this girl first went to a well-known eastern college. The health department took it upon themselves to put it down as pleurisy and did not report it to the family. About six months later we found it was still present, and at that time, it was mentioned to the family.

Last winter I operated upon a recurrence of a Ewing tumor of the ribs. The man had been operated upon several years ago in Italy. We could not get an adequate history from him. He was very uncertain where it had been done and what had been done to him and could not help us at all. Up to the present time, about eight or ten months after operation, he has had no recurrence, so I think it is very unlikely that he will have.

Since this discussion this patient has returned with extensive pulmonary and mediastinal metastasis; the operative site remains clear.

Recently at Bellevue we saw a very interesting tumor of the ribs, about which we came to no conclusion because the patient has not come to operation. The x-ray pictures were those of complete destruction and the disappearance of two ribs over a period of two years with only a few fragments of bone left in the bed of one rib and nothing in the other. A small swelling could be felt upon the chest wall.

I think that the development and maintenance of the Tumor Registry will help us a great deal in these tumors and will bring many more cases to light with adequate follow-ups. That subject we considered last night, and I know Dr. Brunn has much in mind to say to you tomorrow.

DR. ETHAN FLAGG BUTLER, Ithaca, N. Y.—In rural New York and northern Pennsylvania primary chest wall tumors have comprised 0.89 per cent of my series of thoracic cases. Mediastinal tumors have comprised 1.15 per cent of the same series. One of the chest wall tumors was a huge desmoid, weighing 7½ pounds and practically filling the left hemithorax. The diagnosis was made by Chandler Foote of New York. The slides showed dense, fibrous tissue with very little cellular infiltration.

DR. SAMUEL O. FREEDLANDER, Cleveland, Ohio.—I should like to call attention to a type of tumor of the chest wall which may simulate a primary tumor of the ribs. These are neurogenic tumors. I have had experience with one case arising from the intercostal nerve anteriorly. These tumors may reach a large size and insinuate themselves between the ribs so that only a small portion may present outside of the rib, a larger portion extending into the chest extrapleurally. The problem of removal may be very difficult because it may be necessary to remove a large area of rib in order to completely remove all of the tumor. The case that I had was that of a woman aged about 26 years, who had a tumor in the left anterior chest wall about 8 by 6 cm. A biopsy was done, and the diagnosis was neurofibroma. Upon exploring the tumor, it was found that the larger area extended underneath the rib. It was necessary to remove large sections of the sixth and seventh ribs anterolaterally, and the pleural cavity was entered in order to bring about a repair. It was necessary to transplant the diaphragm and attach it higher in order to seal off the pleural cavity. She made an uneventful recovery. It is now three years since operation, and there is no sign of recurrence.

DR. LEO ELOESSER, San Francisco, Calif.—Three or four years ago Dr. Rogers and I saw a child with a painful swelling on his chest and a high fever. Dr. Rogers took a specimen for examination to a competent pathologist, who re-

ported osteomyelitis. The child did not do well, and a tumor developed inside of the chest. This turned out to be Ewing's tumor of the ribs. The child died of huge mediastinal metastases. We have seen one other such tumor of the ribs.

DR. EMILE HOLMAN, San Francisco, Calif.—I should like to call attention to secondary metastasis in the rib sometimes mistaken for primary tumor. A 60-year-old man had had a small papilloma removed from the rectum some three years previous to his admission to the hospital for a large mass in the chest wall which was destroying a rib. The mass was removed and proved to be secondary to a polypoid carcinoma, and the inference was that it came from the rectum.

I should like also to call attention to the possibility of mistaking inflammatory lesions for malignant tumors. A prominent doctor of San Francisco went through the harrowing experience of finding a presumed tumor of one of his ribs, which had produced erosion of the central portion. It was removed with the anticipation of finding a sarcoma, but it proved to be an inflammatory lesion. When we went back over his history, we fund that he had had typhoid some twenty years before. Whether or not this was a residual small cyst originating from a typhoid lesion many years ago, it is impossible to say. We are all acquainted with the fact that occasionally typhoid gives multiple osteomyelitis of the ribs. I had one instance in a small boy in whom every rib was involved in an inflammatory process due to typhoid bacillus. In this same individual, we removed twelve sequestra from the long bones but no sequestra in the ribs.

DR. STUART W. HARRINGTON, Rochester, Minn.—I have been very much interested in Dr. Harper's presentation, particularly in regard to the surgical technical problems associated with tumors of the anterior chest wall. I think primary tumors of the chest wall present many more surgical technical difficulties associated not only with removal of the tumor, but also with the reconstruction of the thoracic wall. This is particularly true in those tumors of the ribs below the second rib anteriorly. I have found that many of these tumors below the second rib can be removed very effectively through a posterior lateral incision and a transpleural method of approach without making any incision in the anterior chest wall. In malignant tumors of the chest wall, I do not believe it is advisable to attempt reconstruction of the thoracic cage, other than the closure of the skin, until sufficient time has elapsed to be certain that there will be no recurrence. In many cases of tumors involving the chest or second rib, the tumors can be approached either by disarticulation of the clavicle or by cutting of the clavicle.

DR. JEROME R. HEAD, Chicago, Ill.—Dr. Harper and Dr. Harrington have both emphasized the difficult technical problems that arise in connection with removal of benign tumors of the chest. I would like to present one such case of a benign chondroma of the manubrium in a woman 35 years old. This tumor had been recognized for over two years and within the past few months had increased rapidly in size. To remove the tumor, it would have been necessary to remove the entire manubrium, including its attachments to the clavicles. We feared that this might permit the clavicles to move inward toward the midline and that the pull of the sternocleidomastoid muscles would elevate them into the neck with the production of an appreciable deformity. In a search through the literature we were unable to find an instance of complete removal of the manubrium. Despite our doubts, the operation was carried out, and we were gratified to find that no appreciable deformity ensued. The inner ends of the clavicles did approach each other slightly, but they were not drawn appreciably upward. The accompanying slides illustrate the pre- and postoperative condition.

DR. HENRY L. CABITT, Brookline, Mass.—I just wanted to mention four patients with chest wall tumors whom I saw on Dr. Graham's service in 1934. They were young adults and were admitted to the hospital in a period of one month. They all had relatively short histories. The x-ray showed a definite mass and bone destruction, and they were all found to be inoperable. The pathologist's report was that they were most likely myelomas. All of the patients had x-ray therapy with some diminution in the size of the mass. That was five years ago. What has happened to them I am not sure, but it is my hope to follow through and see whether any of these patients are still alive.

DR. W. A. HUDSON, Detroit, Mich.—Mention has been made of the possibility that some of these single tumors of the ribs might be metastatic lesions. I wish to call to your attention the case of an adult 60 years of age who complained for a period of six months of pain along the lower border of the ribs on the right. Repeated x-ray studies failed to show evidence of lesions in any of the bony structures in this region. Further examination and laboratory studies gave nothing of a diagnostic value. The patient was kept under observation, and complete x-ray studies were made. At the end of six months, a single destructive lesion was determined in the ninth rib on the right near the angle of the rib. There was a rapid increase in the size of this mass, and on exploration, it was found to be inoperable. Microscopic sections suggested metastatic lesions. The patient came to autopsy, and a small pea-sized adenoma of the adrenal was found. It is possible that some of the single lesions that have been described in the ribs are of adrenal origin.

I have under my care now a 13-year-old child, who has a single destructive lesion in the eighth rib. This has come up over a period of four months. Study of the fluid aspirated from the chest reveals sarcoma cells. This patient is still under observation. A final explanation for the lesion, whether it is primary or metastatic, has not been arrived at. We suspect a pelvic tumor as the origin.

DR. HERBERT MELTZER, Ninette, Manitoba.—I would first like to extend my congratulations to Dr. Harper and to Dr. Janes for their interesting presentations. Dr. Freedlander gave a case very similar to the one I would like to report now. This woman, aged 42 years, presented herself in June, 1937, with pain in the left anterior part of her chest. An x-ray film showed a definite small tumor mass associated with the fifth rib in the anterior axillary line. The history was rather a short one—about two or three months of pain in this region. A therapeutic pneumothorax was performed, and the tumor seemed to be unassociated with the lung. There were no pleural attachments.

I should mention that the thoracoscopic examination was done to demonstrate that there was absolutely nothing to indicate involvement of the lung. The parietal pleura was very vascular, but it was quite smooth and glistening. The removal was done without much technical difficulty. A good length of the fifth rib was removed, as well as chest wall on either side of this tumor mass.

The postoperative course was uneventful, and the woman is perfectly well today. I actually saw her a few weeks ago, practically two years following this removal. A microscopic examination of the tumor mass demonstrated a neurofibroma with malignant changes in the central part of the growth. There was evidence that the malignancy was of low grade, and no x-ray or radium was considered necessary.

DR. THOMAS J. KINSELLA, Minneapolis, Minn.—From the standpoint of differential diagnosis, there are several other conditions which should be considered. Three of these will be illustrated by a series of slides. The first, Ewing's tumor arising from the left fourth rib, occurred in a girl 10 years of

age. Surgical removal of the tumor required excision of large segments of three ribs and adjacent portions of the adherent upper and lower lobes of the lung. Reconstruction of the chest wall, accomplished by transplantation of rib and latissimus dorsi muscle, was satisfactory except for some loss of tissue from local infection. Skin grafting was necessary over this area. This girl is attending school and is in good condition over eighteen months following the operation.

The second condition was presented by a man 68 years of age, who complained of pain along the course of the right ninth rib. Local rib destruction was evident on x-ray films, but no local tumor could be palpated. The lung fields were negative to x-ray studies except for a small soft tissue shadow adjacent to the involved rib. The tumor was found to involve not only the rib but adjacent lung as well, necessitating a partial lobectomy as well as excision of a portion of the chest wall. Microscopic study revealed a squamous-cell carcinoma of the lung involving the nearby rib. No other primary site could be demonstrated. This man is working and in good condition one year after operation.

The third patient, aged 39 years, presented almost the same history and rib erosion as the previous case except for the local tumor. This time, however, the rib destruction resulted from a local abscess secondary to a small dermoid cyst arising under the right eleventh rib posteriorly. Local excision of the rib and cyst was followed by complete healing.

DR. FRED R. HARPER, Denver, Colo.—I was very much interested in this discussion because it confirmed an impression that I had that these tumors are not as rare as they would seem to be. I was disappointed in the literature, or possibly in my inability to interpret the literature, because it seemed entirely inadequate. I feel this present discussion will do much to clarify the classification and the treatment of these tumors of the chest wall.

DR. ROBERT M. JANES, Toronto, Ontario.—I have nothing to add to the remarks of most of those who have discussed the paper, but I should like to thank them for the discussion.

In connection with those remarks upon the secondary tumors of ribs, I would suggest, as I have in the body of my paper, that, when one suspects that a destructive lesion may be metastatic in origin, an aspiration biopsy will often save the patient an unnecessary operation. The interpretation of it in the case of secondary tumors is not, as a rule, difficult. The histopathology of some of the primary tumors is, of course, much more difficult. We have seen typhoid lesions of costal cartilage similar to what Dr. Holman has described and, in one case, recovered typhoid bacilli from the lesion many years after the attack.

So far as the neurogenic sarcomas are concerned, I have not seen any, but the picture would appear to be different from that of the primary tumor. I would merely suggest that experience with them elsewhere in the body would lead one to believe that a very wide removal should be done because of their tendency to recur.

I should like to emphasize the importance of removing the underlying periosteum and pleura along with the adjacent muscle when operating on these tumors of ribs, because, otherwise, complete removal cannot be done and frequent recurrence would seem to be likely.

PECTUS EXCAVATUM (FUNNEL CHEST)

Anatomic Basis; Surgical Treatment of the Incipient Stage in Infancy; and Correction of the Deformity in the Fully Developed Stage

A. Lincoln Brown, M.D.
San Francisco, Calif.

PECTUS excavatum* is that deformity of the thoracic cage characterized by a funnel-shaped depression of the sternum, the apex of which is located at approximately the level of the junction of the xiphoid with the body, or gladiolus. All degrees of depression are to be observed, from the slightest up to such a pronounced state wherein the point of greatest depression brings the distal end of the body of the sternum to within 1 or 2 cm. of the vertebral column.

It is the purpose of this contribution to review the heretofore suggested causes of pectus excavatum; to present what is the probable cause thereof; and to offer, with this as a basis, surgical procedures both for its prevention and alleviation. These procedures have been developed after anatomic studies and our experiences in surgical interventions upon the condition. Five operative cases of my own are reported.

A definite distinction is to be made between the indications for operation in infancy and in the fully developed state. Cases 3 and 4 are examples of the developing condition in infancy. Obviously, it is impossible to prognosticate during this period just how marked the ultimate deformity might become in each instance. The surgery suggested during infancy is simple and should at least prevent the full development of the deformity, thereby obviating the necessity of a major procedure later in life. Prevention or correction of the defect is called for primarily for two reasons. First, definite functional restrictions upon the circulatory and respiratory mechanisms may ensue, or exist. Second, there is a definite esthetic value to operation, this being especially true in women.

HISTORY AND THEORIES OF ORIGIN OF PECTUS EXCAVATUM

The cognomen and modern interest in the condition dates from the exhaustive presentation in 1882 by W. Ebstein.[1]

But it is here to be noted that, in 1921, a report made in 1596 by J. Bauhin[2] was rediscovered by E. Ebstein.[3] Not only had Bauhin accurately described the condition, but furthermore, he stated that the pull of the diaphragm is the

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*The term "pectus excavatum" is synonymous with the German expression *Trichterbrust*.

causative factor. As we had arrived at this conclusion ourselves, we were naturally interested to find that about 250 years ago this theory had been considered, but had been practically overlooked in the passage of time. We were still further fascinated, upon reading his case history, to observe that, up to a point, it could well pass for that of one of our own cases (Case 1). I believe it to be of sufficient interest to give the Bauhin case report in its original.

> (Observationum Medicarim. Liver II, Observ. 264, Franefurti 1600, S 507.)—Joh Bauhinus.
>
> Sterni cum costis et interna reflexio nativa, spiranda difficultatis-caussa.
>
> Pater meus ostendit mihi puerum septum annorum, apud Nobilem de Andlau, cui cartilago ensiformis, et sterni pars aliqua cum costis ad internas partes admodum reflectebatur, ita ut magna ibi cavitas appareret. Videtur diaphragma augustitus eas contrahere partes. Ab ipse nativitate hoc vitio instrumentali laboravit, cum difficultate spiranda, obnoxius tussi est. Nunc gravissime laborat, ita ut videatur sufficationis periculum imminere, viscida admodum spint. Ait Domina de Andlau, se habere nepotem, multo minorem ex eodem nata ex eodem affectum vitio. Ex observ. D. D. Johani Bauhin.

Likewise Eggel,[4] in 1870, among several theories as to possible etiology, offered the idea that the comparative elasticity and relative insecure fixation of the lower ribs might allow the diaphragm to pull the lower end of the sternum inward during inspiration.

ANATOMY*

The sternum consists essentially of three parts connected on each side with the cartilages of the first seven ribs. Superiorly it acts as a support to the clavicle. The three parts are, respectively, the manubrium, the gladiolus or body, and the xiphoid process. In early life the body is formed by the fusion of four segments, and in later life the xiphoid usually joins this fusion. On the other hand, the manubrium usually remains separate throughout life, a true joint persisting between the manubrium and the gladiolus. The prominence caused by this joint is called the angulus sterni, or angle of Ludwig. It is of particular interest to us to observe that the beginning of the conical depression noted in *Trichterbrust* occurs at this joint, and no matter how pronounced the depression of the lower end of the sternum becomes, the manubrium remains in its normal plane.

The various portions of the sternum, the ribs, and the xiphoid are firmly fixed by dense ligamentous fibers. These include: (1) the articular capsules surrounding the joints between the true ribs and the sternum; (2) the radiate sternocostal ligaments forming a thick fibrous membrane (membrana sterni) which envelopes the sternum and intermingles with similar fibers from the opposite side; (3) the interarticular sternocostal ligament which strengthens the joint between the manubrium and the gladiolus with the second rib on either side; (4) the costoxiphoid ligaments connecting the anterior and posterior surfaces of the seventh and sometimes the sixth costal cartilages with the front and back of the xiphoid process.

For our purpose it is also necessary to recall that the diaphragm has two slips which arise from the undersurface of the sternum near the junction of the xiphoid with the gladiolus and that the diaphragm, furthermore, has a diffuse origin upon the inner surfaces of the cartilages and adjacent portions of the

*The cooperation and advice of John B. deC. M. Saunders, M.D., and the Department of Anatomy are gratefully acknowledged.

lower six ribs on either side. The transversus thoracis is a thin plane of muscle and fascia arising from the undersurface of the lower third of the sternum and xiphoid process, whose fibers run upward and laterally to be inserted into the lower edges of the cartilages of the second and sixth ribs. The dome-shaped diaphragm consists of fibers which radiate toward a central tendon.

In the description of the anatomy, to continue from the xiphoid abdominally, we wish to point out that the ligamentous fibers which unite to form the linea alba are really a continuation of the same fascial structure which surrounds the xiphoid and the sternum (membrana sterni).

Fig. 1.—View from the inside of the chest and the abdomen, showing the sternal attachments of the diaphragm. The substernal ligament is seen to be a continuation of the fibers of the linea alba.

Consideration of these basic anatomic facts shows clearly that there is only one muscular force which can draw the sternum inward with the point of maximum indentation at the sternoxiphoid junction; that is the diaphragm and, in particular, those fibers of the diaphragm which have their origin on the sternum.

The continuation of the membrana sterni and linea alba must be stressed. From anatomic studies and surgical observations, we desire to point out, not only that this membrane exists posteriorly, but that it is a very firm definite structure 2 to 3 cm. in width, extending the length of the sternum, and merging with the posterior fibers of the linea alba. For this portion of the membrane, the name substernal ligament is suggested.

Displacement of the heart in these patients has always been a point of interest. Groedel[5] stated that the heart was always displaced to the left. Actually, it tends to be fixed near the midline by the diaphragmatic attachment of the

pericardium. Primarily either one of two conditions may exist, even in patients with marked depressions of the sternum. Either the heart may be held in the midline and encroached upon by the depressed sternum, or it may be displaced either toward the left or right thoracic cavity. The cases reported are examples of the three possible cardiac positions. The greatest cardiac embarrassment appears to be present when the heart is fixed near the midline and is directly compressed by the depressed sternum. Lateral displacement does not appear to be a great cardiac handicap. Cases have been reported with only 1 cm. space between the vertebral bodies posteriorly and the depressed sternum anteriorly (Pohl[6]).

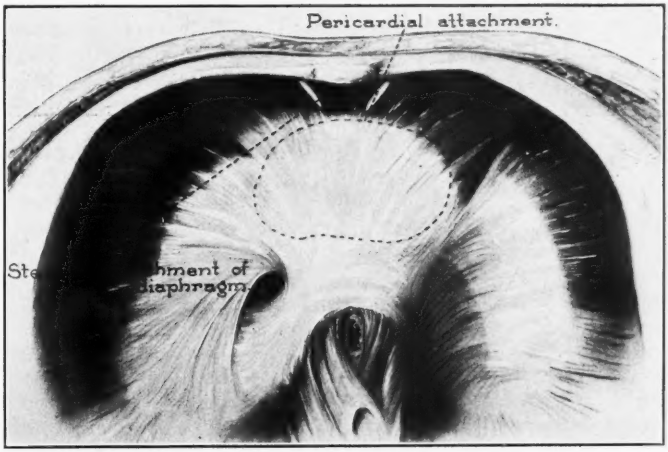

Fig. 2.—Sternal attachment of diaphragm seen from below. Shortening of these anteroposterior fibers of the diaphragm accounts for the fixation of the lower end of the sternum in the depressed position. The pericardial attachment to the diaphragm suggests why the heart tends to be fixed in the midline and thus encroached upon by the depressed sternum.

ETIOLOGY

Many etiological factors have been proffered.[7-9] These include:

1. Various intrauterine pressure abnormalities, such as a knee or an elbow pressing on the fetal sternum.
2. Intrauterine overdevelopment of the corpus sterni.
3. Arrested development of the sternum.
4. Rachitic influence on the development of the sternum, either alone or associated with the development of the entire thoracic cage.
5. Obstruction in the upper air passages, especially obstruction as from hypertrophied tonsils and adenoids.
6. Genetic factors.
7. Neurological factors.

I believe that the various intrauterine pressure theories may be dismissed as being essentially fantastic. The chest deformity commonly noted in rickets somewhat suggests a possible relationship with that seen in *Trichterbrust,* but on close scrutiny we note that none of the cardinal rachitic findings are present in any case of *Trichterbrust.* Furthermore, *Trichterbrust* has never been reported in an authenticated case of rickets. It is difficult to conceive that obstruction to the upper air

passages is the causative factor, since such pathology is so common, but is by no means to be observed in an unusual percentage of cases of *Trichterbrust*. We do, however, believe that genetic and neurological factors play important etiological roles.

The importance of the genetic factor is most forcibly demonstrated in the report of Nowak[7] who, in 1936, examined 30,000 Viennese school children and found 12, or 0.4 per cent, to be afflicted with the condition. All of these were found to have had indications of the deformity since birth. He then traced the families of these twelve and found that heredity played an obviously important role. In these families he examined 106 individuals. The condition was observed in 41 of them (38+ per cent), 24 being male and 17 female. This hereditary factor is confirmed in our own cases.

Theories of etiology and the operative procedures which it is our purpose to describe were arrived at, to a great extent, by our experiences in certain clinical cases. Hence, to lay a basis for our opinions and proposals, it appears logical first to present the cases operated upon and then to give our deductions in the light of our experiences.

CASE REPORT

CASE 1.—J. T. W., white male, 7 years of age, first entered the University of California Hospital, May 11, 1937. Chief complaints were cough, weakness, malaise, loss of weight, and daily fever since January, 1937.

Present Illness.—The patient has always had a tendency to be slim, but, except for this, was well until Jan. 11, 1937, when he developed malaise, temperature of 104° F., cough with occasional "blood-streaked" sputum, and pain in the left chest. With these symptoms, he was dyspneic, had marked diaphoresis, and was so weak he was unable to assist himself in bed. These symptoms remained acute for the following three or four days, and then he showed some improvement but continued to have cough, blood-streaked sputum, temperature of 102° to 104° F. each afternoon, weakness, and malaise until the middle of February. Despite these symptoms he slowly became ambulatory. He continued to lose weight, amounting to 3 or 4 pounds. Despite his being up, the above symptoms continued except for a slight gain in strength and appetite, until one week before entry, when all of the previous symptoms became much more severe. His dyspnea progressed and his fever was elevated to 104° F., with pallor, malaise, and marked weakness, in addition to his cough and sputum. He had no family history of tuberculosis or other chest diseases. The patient had lived all of his life in the San Joaquin Valley (Fresno). His systems were negative except for the fact that he was sensitive to colds, and in addition had had a congenital depression of the sternum, with dyspnea on exertion practically all his life.

Physical Examination.—This revealed a very thin child, 7 years old, who appeared weak and clinically ill. He had a frequent productive cough, with no dyspnea or cyanosis while in bed. He had a generalized *lymphadenopathy*. The *trachea* was deviated to the right. *Chest* showed a deep inward depression of the sternum (about 3 inches in depth). The left chest showed a lag, with equal diaphragmatic excursion bilaterally. Fremitus, breath, and voice sounds were more pronounced generally in the right chest than in the left. Posteriorly on the left, there was a 2-inch longitudinal area of dullness and depressed breath and voice sounds just below the left apex. No râles were heard. The *heart* was in the right chest, with the apex beat seen in the fourth to sixth intercostal space 1 cm. to the right of the midclavicular line. There was a soft systolic murmur over the apex, and the pulse was equal and synchronous. Examination of the *abdomen* was negative. There was no edema or clubbing of the extremities.

Laboratory.—Urine was negative. Blood tests showed: red blood count, 6,600,000; hemoglobin, 80 per cent; white blood count, 24,100, with 88 per cent polymorphonuclears. Tuberculin tests, human and bovine 1:1000, were negative.

Impression.—Congenital cystic disease with secondary infection in the left upper lobe, and, second, possible multiple small abscesses in the left upper lobe following an unresolved pneumonia. *Trichterbrust* was pronounced.

X-ray Examination.—On May 11 an extensive process involving the entire left lung was revealed, with patchy infiltration in the upper two-thirds of the lung, becoming confluent toward the cardiophrenic angle. Numerous areas of diminished density were distributed throughout the left lung, particularly in the upper portion of the process. At least one well-defined fluid level was seen lying at the level of the eighth vertebra in the posterior part of the chest, with considerable reaction about this cavity. There was well-defined infiltration about many of the areas described. The marked depression of the sternum was felt to account for the displacement of the mediastinum to the right. The lipiodol studies on May 13 confirmed the films.

On May 13, 1937, *bronchoscopy and lipiodol instillation* showed the trachea to be deviated slightly to the right, as was the carina. Both orifices of the main stem bronchi appeared normal. The left upper lobe could not be filled.

The Wassermann test was negative. The stool was markedly positive for occult blood. Acid-fast stains of the sputum and gastric washings were repeatedly negative.

On May 15, one acid-fast organism was seen in the gastric lavage specimen, but acid-fast organisms were not seen in repeated specimens after this time.

Discharged.—The patient showed daily symptomatic improvement while in the hospital, but continued to run a low-grade afternoon temperature. He was discharged on May 23, 1937, to await returns of guinea pig inoculation.

Re-entry.—He re-entered this hospital on June 10, 1937, with essentially the same history and physical findings. A diagnosis of cystic disease of the left upper lobe, probably congenital, and possibly postpneumonic, was made, with dextracardia secondary to his congenital depression of the sternum *(Trichterbrust)*.

Operation.—Probable congenital cystic disease of the left upper lobe was diagnosed. Associated with this were a marked congenital pigeon breast that was reflected slightly to the left and a secondary dextracardia. Removal of the sternum had been suggested as a possible means of increasing the patient's pulmonary reserve, preliminary to a left upper lobectomy. The operation (June 14, 1937) was subtotal resection of sternum under local anesthetic and gas and oxygen.

A curved semicircular incision from the second left rib just lateral to the costochondral articulation was carried forward to the right lateral aspect of the sternum, and a semicircular line was extended down the sternum to the level of the sixth right costochondral articulation and then carried to the left again to the level of the sixth left chondrocostal articulation. The incision was developed through the skin, subcutaneous tissues, and superficial fascia.

The lower third of the sternum was markedly depressed and veered toward the left. The patient had a shallow thoracic respiratory excursion, and during the operative procedure, his breathing was chiefly of the abdominal type. When the sternum was removed, there was no appreciable difference in the thoracic wall excursion.

Technique.—The skin flap on the left was carried about 4 cm. lateral to the sternum by sharp dissection between the superficial fascia and the anterior interstitial ligaments and the pectoral fascia. The right skin flap was then elevated by sharp dissection to the same plane, until the right costochondral articulations of the third, fourth, and fifth ribs were exposed. The anterior interstitial and chondro-

sternal ligaments of the second, third, fourth, and fifth ribs on each side were incised and separated from the costochondral articulations by blunt dissection with a periosteal elevator; the perichondrium was then stripped away with the same instrument. The costochondral articulations were severed, and the sternum was severed with a scalpel between the manubrium and gladiolus. The third, fourth, and fifth

Figs. 3*a* and 3*b*.—Case 1. Comparative anterior and lateral views of the patient, showing depression of sternum and flexion of chest on abdomen before operation and relief secured by surgical intervention.

left articulations were severed first, and then the third, fourth, and fifth on the right side; the superior portion of the sternum was elevated slightly, and with the periosteal elevator, the posterior sternal ligament, which presented as a firm, fibrous, interdigitating band, was separated until the ensiform process was reached. The sixth costochondral articulations on the left and right sides were then severed, respectively, and the gladiolus was separated from the ensiform

process with the curved scissors. Hemostasis was maintained during this procedure with straight arterial forceps and either coagulation on the finger points or tying with 000 catgut on the definite vessels.

There was very little bleeding throughout the procedure. The anterior mediastinum was not entered, as far as we could tell, and the posterior sternal ligaments appeared to be intact at the end of the procedure. As mentioned before, the respiratory excursion of the patient as to the thoracic wall movement was not affected appreciably by the procedure. The heart appeared to be in the

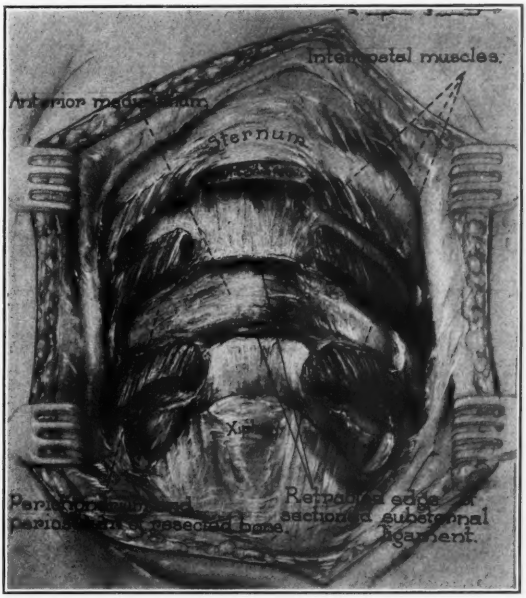

Fig. 4.—Semidiagrammatic representation of retraction of cut edges of substernal ligament. This is the only point at which the mediastinum need be entered.

same position and did not seem to have shifted toward the midline as had been anticipated. The substernal ligament was very thick and could not be raised by direct traction. As this seemed to maintain a depressed position and keep the chest somewhat flexed on the abdomen, it was thought advisable to remove it. A transverse incision was made of the substernal ligament at the level of the fourth interspace. Immediately, the two ends pulled apart a distance of about 3 cm., thereby allowing relief of the flexion of the chest on the abdomen and a considerable forward extension of the mediastinal contents. The skin flaps were then approximated with interrupted sutures of fine silk, and they were closed rather tightly, but without undue tension. There was a definite dead space left between the posterior sternal ligament and superficial fascia. No drainage was used. Alcohol and dry dressings were applied, and the patient was sent to ward in good condition.

Course.—The patient made an uneventful recovery following this operation.

He was *bronchoscoped* on July 6 and July 12, 1937, in an unsuccessful attempt to establish drainage through the left upper lobe opening. However, following these examinations, the patient showed daily improvement, and his temperature dropped to normal.

He was discharged on July 23, 1937, much improved, with advice to return in from six months to a year for possible lobectomy or pneumonectomy.

Re-entry (Aug. 3-27, 1937).—He re-entered on Aug. 7, 1937, with an interval history of having gained in weight and strength, but with continuation of cough and production of a scant amount of sputum each day, daily afternoon fever, and diaphoresis. His appetite had been good, and he had had no chest pain, blood-streaked sputum, or dyspnea.

Re-entry (July 21—Aug. 25, 1938).—Left upper lobectomy was performed by Dr. Harold Brunn August 3. The patient's heart remained on the right side. He was discharged as well on Aug. 25, 1938.

DISCUSSION

The experience with Case 1 led to the following conclusions:

1. Elevation of the depressed portions of the sternum, cartilages, and ribs alone may correct the obvious skeletal deformity, but the contracted and depressed substernal ligament must also be sectioned. This allows for extension of the chest on the abdomen and prevents regeneration of bone in a depressed position from the otherwise depressed ligament and its attached periosteum and perichondrium. Failure to section this ligament has most likely been the causative factor of so-called recurrences in previously reported unsuccessful cases.

2. Section of the substernal ligament, furthermore, corrects the deformity consisting of the flexion of the chest upon the abdomen, general sunken appearance of the chest, and round shoulder habitus. This deformity is present in all instances of *Trichterbrust* to a greater or lesser degree.

3. With the above noted anatomic facts and operative experience as a guide, a simple and more successful operative procedure might be devised. (Case 2 describes this technique.)

CASE REPORT

CASE 2.—H. G., white male, aged 22 years, single, entered the hospital on Aug. 31, 1938. He had had a depressed, funnel-shaped chest since birth. It increased progressively in extent as he grew. The definite symptom associated with this was dyspnea on exertion. There was no associated pain, cough, pressure sensation, or evidence of definite circulatory failure. He had had frequent colds in the past.

Ten years ago, the patient was struck in the right eye with a baseball and developed acute glaucoma, which resulted in complete loss of vision in that eye. At this time, it was noted also that the patient has dislocated lenses in both eyes and a cataract in his left eye, which was removed surgically. His vision was markedly diminished.

The patient's father, brother, and sister had funnel-shaped chest deformities, but to a less degree than the patient.

Physical Examination.—The patient is tall and stoop-shouldered with prematurely gray hair. There was a marked sunken appearance on the anterior wall of the chest. The body of the sternum was involved in the depression which measured approximately 10 cm. in its vertical length, 8 cm. in width, and 5 cm. in depth. This deformity was due not only to a depression of the sternum, but also to an abnormal

posterior curve of the costochondral cartilages, chiefly on the left side. Examination of the lungs was negative, except for a fine expiratory râle which appeared occasionally. Respite the depression of the sternum, the heart was not displaced. Point of maximal impulse was in the fifth interspace just inside the midclavicular line. Area of cardiac dullness was not increased. A_2 was greater than P_2. M_1 was

Figs. 5*a* and 5*b*.—Case 2. Comparative anterior and lateral views of patient, showing depression of sternum and flexion of chest on abdomen before operation and relief secured by surgical intervention.

greater than M_2. P_2 was split. There was a loud pulmonic systolic murmur when the patient was in complete expiration. There was no arrhythmia. Blood pressure was 140/90 in the right arm, 130/90 in the left arm; vital capacity, 4,300 c.c.; chest depression capacity, 97 c.c. of water. Initial venous pressure was 6 cm. with a drop to 4.5 cm. on compression of the right upper quadrant. Ether time was 8 seconds; decholin time, 14 seconds. The conclusion was reached that the venous pressure and circulation time were normal.

Laboratory Examination.—Wassermann and Kahn tests and urinalysis were negative.

Blood tests revealed: hemoglobin, 110 per cent; red blood count, 6,000,000; white blood count, 5,500, with 78 per cent polymorphonuclears, 1 per cent eosinophiles, 1 per cent basophiles, 17 per cent lymphocytes, and 3 per cent monocytes.

On an x-ray of the chest, made Sept. 2, 1938, there was a slight increase in the hilar markings. On the whole, however, the lung field appeared to be clear. There was no evidence of any acute or chronic pneumonic pathology, and the cardiac shadow was within normal limits. Electrocardiograms were suggestive of auricular hypertrophy.

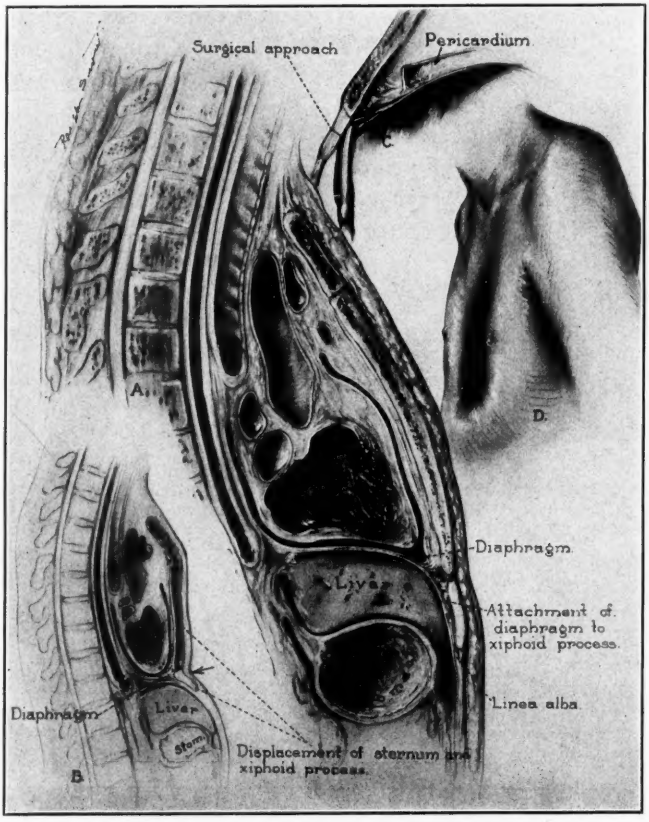

Fig. 6.—*A.* Normal anatomic relations. Site of sternal attachments of diaphragm. *B.* Restriction of heart by depressed sternum with shortened anteroposterior diameter of diaphragm. *D.* Typical pectus excavatum drawn from life (Case 2, H. G.).

Operation was performed on Sept. 7, 1938, under cyclopropane anesthesia. After transecting the third, fourth, fifth, sixth, and seventh costochondral cartilages, following which a V-shaped transverse osteotomy incision was made across the angle of Louis, the xiphoid process was excised and the rectus abdominis muscle attachments were released from the sternum; it was noted that the depressed portion of the sternum was still well fixed in its depressed position by the attachments of the

contracted diaphragm to the internal aspect of the sternum. It was also noted that during inspiration the depressed segment of the body of the sternum was drawn strongly downward by the diaphragmatic pull. After dissecting the medial aspect of the sternum free from the diaphragmatic and transversus thoracis muscle attachments, the sternum was well mobilized and could be easily elevated from its depressed position. It no longer had a tendency to be drawn inward by the inspiratory act. The operator was impressed by the fact that the release of the diaphragmatic attachments and the transversus thoracis muscle attachments to the medial aspect of the sternum was the greatest single factor in correction of depressed sternum. This must be done to maintain the correction.

Procedure.—A vertical, slightly curved incision with its convexity toward the left was made, beginning at the angle of Louis in the midsternum and extending downward to the xiphoid process. The perichondrium over the third, fourth, fifth,

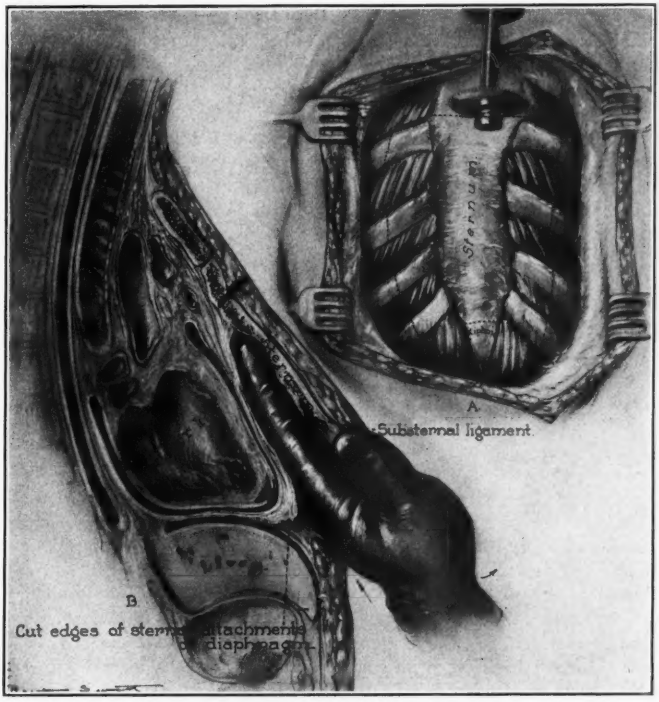

Fig. 7.—*A.* Dotted lines indicate where sections of cartilage and ribs are to be removed subperichondrally or subperiosteally; point of section of xiphoid and substernal ligament immediately beneath; site of removal of wedge from anterior portion of sternum by rotary saw. *B.* Separation and elevation of sternum from substernal ligament.

sixth, and seventh costochondral segments was then incised parallel to these segments, and the perichondrium was stripped free from the costochondral segments on both the right and left sides. Each costochondral segment thus exposed was then transected, using bone shears, and dividing the costochondral segment near its junction with the sternum in each instance. Costochondral segments, approximately 2 cm. long, were resected from the fourth, fifth, sixth, and seventh ribs, bilaterally. At this point, a transverse wedge-shaped segment of bone was excised

from the anterior aspect of the sternum at the junction of the manubrium and the gladiolus, using the electric circular osteotomy saw. After completion of this procedure, the depressed portion of the sternum could be elevated with some effort, but would not remain in this corrected position due to the strong pull of the rectus abdominis muscle, the sternal attachments of the transversus thoracis muscle, and also the diaphragmatic attachments of the medial aspect of the sternum.

The xiphoid process was then resected from its sternal attachments. The lateral attachments of the rectus abdominis muscle to the distal sternum were transected, but despite this, the ability to elevate the depressed portion of the sternum was not greatly increased.

It could be demonstrated at this time that the most significant factor in holding down the distal sternum was the strong diaphragmatic attachments to its internal surface, supplemented by the transversus thoracis muscle attachments. We noted also at this time that during the inspiratory phase the depressed portion of the sternum was strongly drawn inward as the result of the diaphragmatic attachments. The diaphragmatic attachments and the transversus thoracis muscle attachments were stripped free from the internal aspect of the sternum, following which the gladiolus sterni could be freely elevated to the desired position and this elevation of the sternum was strongly maintained by the insertion of two laterally placed drill holes through the manubrium sterni and the gladiolus sterni above and below the transverse osteotomy site. Using No. 20 gauge silver wire, the manubrium sterni and gladiolus sterni were wired together at this osteotomy site. This procedure maintained the depressed portion of the sternum in a strongly elevated position with no tendency for it to return to its original depressed position during the respiratory action. Single drill holes were then inserted through the transected ends of the fifth costochondral cartilage segments, and these cartilage ends were approximated in strong apposition by a single through and through No. 20 gauge wire. Single drill holes were then inserted distally at the lateral aspect of the gladiolus, and a long No. 20 gauge silver wire was inserted through the right drill hole and brought out through the left drill hole, leaving the ends of the silver wire long; each of these long silver wire ends was then brought out through the corresponding skin flap by means of a large cutting edge wire needle. The incised superficial skin flaps were again retracted and the previously freed rectus muscle attachments were sutured to the periosteum over the distal sternum, using interrupted No. 2 chromic catgut sutures. In addition, adjacent soft tissue which had previously been freed from the lateral aspect of the sternum was then sutured to the periosteum of the sternum by means of interrupted No. 2 chromic catgut sutures. It was felt that this procedure would insure an adequate blood supply to the elevated portion of the sternum. All bleeding points were controlled, and the superficial skin flaps were then approximated, using through and through, interrupted braided silk retention sutures. The skin was then more neatly approximated, using interrupted black silk sutures on straight needles.

At this point, large oval rubber sponges, measuring $10 \times 8 \times 3$ cm., were glued to the lateral aspect of the anterior chest wall just inferior and lateral to each nipple, and the Jacob's ladder was placed transversely across the chest so as to rest on these large rubber sponges. The ends of the Jacob's ladder were firmly sutured to the rubber sponges. The long silver wire ends, acting as forward traction upon the depressed portion of the sternum, were then placed about the central rungs of the Jacob's ladder, and the wire ends were strongly united by twisting. This silver wire traction apparatus was apparently not necessary for maintenance of the elevated portion of the depressed sternum in its new

position, but was used to insure against future depression of this elevated portion of the sternum. Dry dressings were then applied over the incision and the patient was returned to the ward in good condition.

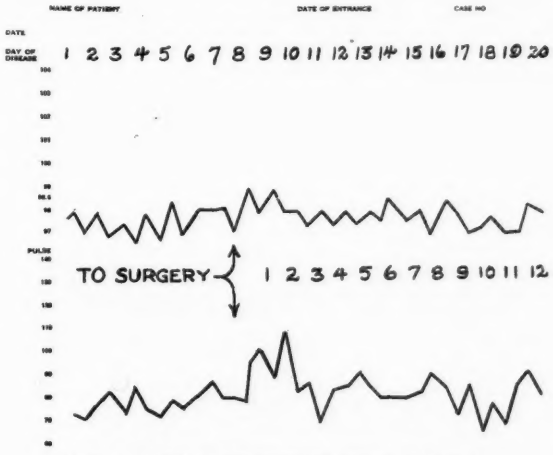
NAME OF PATIENT
DATE OF ENTRANCE
CASE NO
DATE
DAY OF DISEASE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
PULSE
TO SURGERY
1 2 3 4 5 6 7 8 9 10 11 12

Fig. 8.—Chart of postoperative course in Case 2.

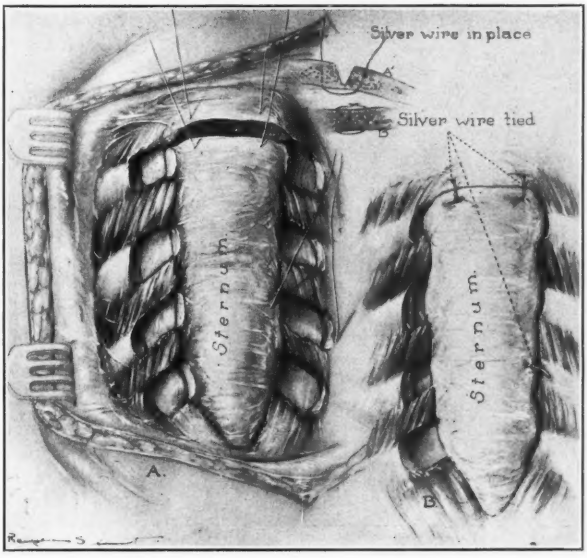

Fig. 9.—*A*. Points of insertion of wire sutures to maintain elevation of sternum. *B*. Position of parts after wires are tied. Sternum now elevated. *A'* and *B'*. Sagittal section of sternal wedge before and after elevation of sternum.

Postoperative Course.—The patient had an essentially uneventful postoperative course. Aside from the usual nausea during the first postoperative day, he had very little discomfort incident to the operative procedure. He was up and about the first postoperative day and daily thereafter. His dyspnea and inanition have de-

creased constantly and to date since the operation. On the twelfth postoperative day, a fluctuant area in the midportion of the wound was incised, with evacuation of approximately 60 c.c. of serous fluid. Aside from the very small amount of serous drainage which appeared for the next three or four days, the postoperative course was entirely uneventful, and the wound healed satisfactorily without infection.

DISCUSSION

From the experience with Case 2 the following conclusions were drawn:

1. *Operative Procedure.—a.* Transverse section of the xiphoid and underlying membrane (substernal ligament) immediately gave access to the undersurface of the sternum.

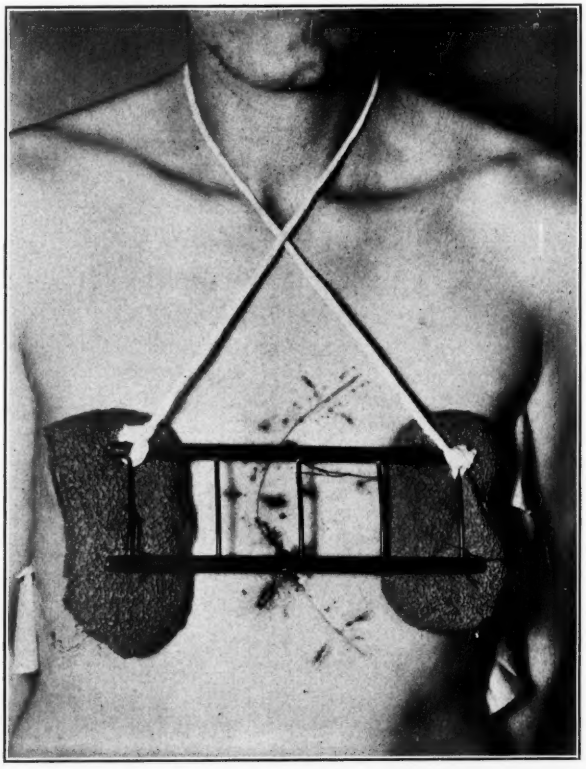

Fig. 10.—Ambulatory apparatus providing safety factor by holding elevated sternum should an external force accidentally press the sternum inward before bone union has taken place. Jacob's ladder rests on sponges glued to the skin, and a wire through the distal end of the sternum is tied over the bars. (Photograph of patient [Case 2], five days postoperatively.)

b. The excision of a transverse wedge of bone through the anterior table at the upper end of the sternum where the depression began (Fig. 9) allowed for elevation of the lower end of the sternum. The

final degree of correction of the depression or, in other words, elevation of the lower end of the sternum, was regulated entirely by the width of the base of the wedge section removed.

c. Stripping the sternum from the substernal membrane (ligament) through the inferior approach was simple and greatly diminished the danger of entering the mediastinum. (This is in agreement with the suggested operative technique described by Truesdale.[10])

d. Fixation of the sternum (Figs. 9*A* and 9*B*) in the elevated position was accomplished by suturing the approximated edges of the removed wedge with wire sutures. Further fixation was obtained by another wire suture through a distal end of the sternum which approximated a rib stump laterally. As a safety factor, a temporary wire suture may be placed through the lower portion of the elevated sternum, the ends of which suture are brought out through the skin and ultimately tied over a bar (Jacob's ladder) which is placed transversely across the chest at the level of the suture. This bar may rest on sponge rubber pads, glued to the skin (Fig. 10). This is a safety factor and may not prove to be essential in the technique.

2. *Results Attained by This Operative Technic.—a.* The mediastinum need not be entered except for the small transverse incision of the substernal ligament. Thereby, the dangers of mediastinal infection, pneumothorax, and hemorrhage are greatly diminished or eliminated.

b. Any degree of elevation of the depressed bone which is desired can be secured.

c. Firm fixation of the elevated sternum is simply made.

d. Freedom of motion of the patient in bed is possible immediately after operation, as is early return to the ambulatory state (in this instance on the first postoperative day).

SURGICAL INTERVENTION IN INFANCY

We recently observed a patient with funnel chest in what may be called its developmental state. A child, 29 months old (Case 3), presented a marked, but flexible, depression which was increased greatly during inspiration and flattened markedly on expiration. One readily observed that the point of greatest traction occurred at about the level of the junction of the gladiolus and the xiphoid. Interfering with the progress of the deformity seemed advisable to us. If the force tending to pull the sternum inward could be eliminated, or at least lessened, then, possibly, as the child developed and the thoracic cage became fixed, a fully developed funnel chest would not ensue. In order to attain this end it was proposed to section the sternal attachments of the diaphragm and the substernal ligament. This procedure was carried out as described in the following case report.

CASE 3.—J. C. T., white male, aged 2½ years, failed to gain properly since birth and had pectus excavatum since birth.

Present Illness.—The patient first entered the University of California Hospital in May, 1938, at the age of 29 months. He was born at full term with normal delivery, but had failed to gain properly. He had had some difficulty in breathing at the age of 1 month and was believed to have an enlarged thymus gland. He did not improve with x-ray treatment. Adenoidectomy was performed at the age of 6 months with improvement in breathing. Despite many dietary changes, he still failed to gain properly and developed frequent bouts of upper respiratory infection, vomiting, and of diarrhea with stools of very foul odor. The mother had noted a marked recession of the sternum at birth which had persisted up to time of entry. She had learned that she was syphilitic six years before but had received adequate treatment. Two previous Wassermann tests on the patient were negative.

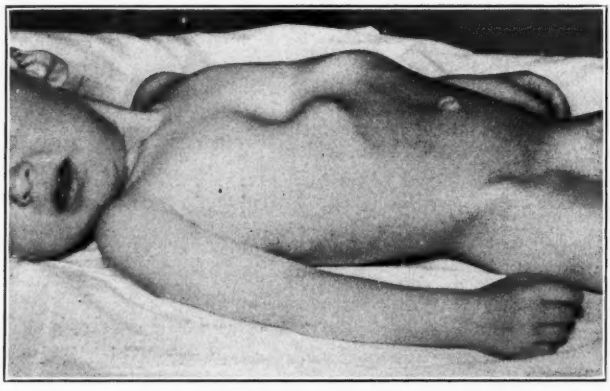

Fig. 11.—Case 3. Depression of the sternum during inspiration.

Family history was irrelevant except for the fact that the patient's father had had a depressed sternum present since birth although it was not very marked.

Past History.—The patient had had pertussis at the age of 2 years, frequent colds, and otitis media. His development was normal except that he did not gain weight and remained undernourished.

Physical examination revealed a pale, thin, undernourished boy of poor posture, with protuberant abdomen, wasting of gluteal muscles, and poor tissue turgor. There were enlarged cervical, axillary, and inguinal lymph nodes, discrete and hard. The head was flattened posteriorly. Examination of the ears was negative except for a peculiar external configuration of the left ear. There was a watery discharge from the nose, congestion, and difficulty in breathing. He had ptosis of left upper eyelid. Mouth hygiene was poor, with markedly hypertrophied and cryptic tonsils. There was a marked flattening of the chest anteriorly and posteriorly, with a deep indentation of sternum most marked at the gladiolus and xiphoid. Examination of the lungs was negative except for stertorous respirations. There was some displacement of the heart to the left. The abdomen was soft and flaccid, with marked protuberance. The genitals were normal; extremities, flaccid; buttocks, flattened; reflexes, physiologic.

The impression was (1) pectus excavatum; (2) chronic respiratory infection; and (3) early celiac disease. Because of a diagnosis of celiac disease the patient was placed on a celiac regimen following tonsillectomy and adenoidectomy. He was then discharged on June 26, 1938, because it was felt that he should be built up more before surgery was attempted on the sternum.

Re-entry: On Sept. 27, 1938, the patient was readmitted for operation. He had improved remarkably since discharge and had gained weight. Tissue turgor, color, and flattened buttocks were all improved but still not normal. Depression of sternum appeared even more marked, and by a comparison of actual measurements at this admission and the previous one, it was seen that the circumference of the chest at the site of depression was actually smaller, showing that depression was becoming more marked.

Operation.—On Oct. 10, 1938, the substernal ligament and sternal attachments of diaphragm were sectioned under drop ether anesthesia.

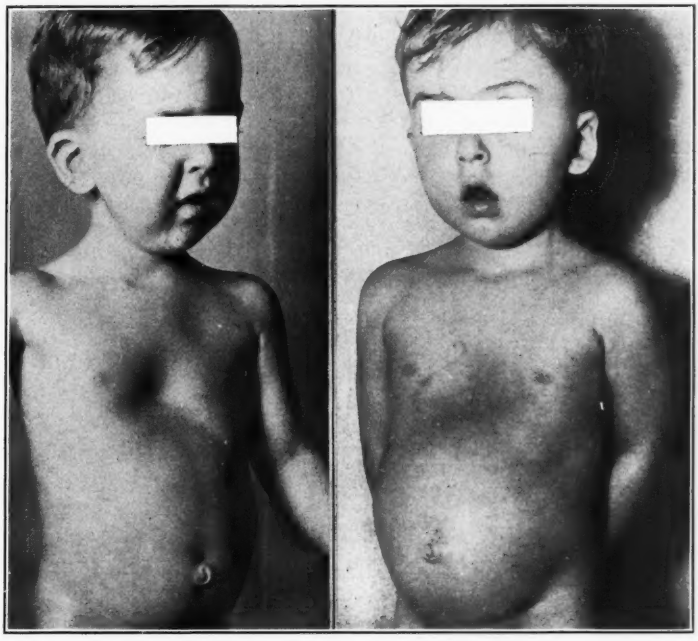

Fig. 12.—Case 3. Appearance of patient before and after section of sternal attachments of diaphragm.

Procedure.—A short vertical incision approximately one inch in length was made in the midline directly over the xiphoid sternal junction. This was developed down through the underlying soft tissues until the junction of the xiphoid and the body of the sternum could be seen. This joint was divided by means of blunt and sharp dissection, and then the substernal ligament was divided. Freeing of the sternal attachments of the diaphragm was accomplished by inserting a periosteal elevator through the divided xiphoid sternal joint and pointing it upward for about an inch and then sweeping the elevator out laterally in both directions and releasing the diaphragmatic origins on either side. Following this it could be seen on inspiration, when the diaphragm moved downward, that the depression was not nearly so marked as before dividing the attachments. The subcutaneous tissues were approximated and closed with interrupted sutures of No. 000 catgut, and a few interrupted sutures of fine black silk were used for the skin. A dry dressing was applied, and the patient returned to the ward in good condition. He was discharged Oct. 17, 1938.

DISCUSSION

From the operative experience with Case 3, it was observed:

1. By means of a simple procedure, the substernal ligament can readily be sectioned and the sternal attachments of the diaphragm safely freed.

2. In consequence of the sectioning of the substernal ligament and the sternal attachments of the diaphragm, there resulted an apparent marked decrease in the degree of depression of the sternum, previously noted during inspiration. Naturally no final judgment as to the value of this procedure can be made until the patient has been observed over a period of years.

3. Since the operative procedure employed here appears to be essentially safe and simple and to accomplish its purpose, its use in developing cases of pectus excavatum is suggested as a possible means of arresting the progress of the deformity.

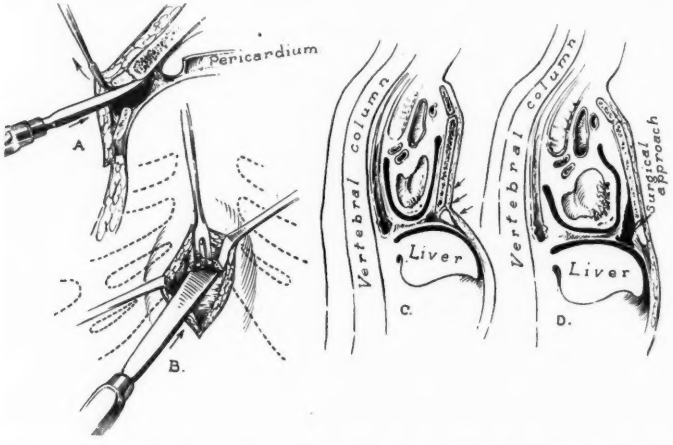

Fig. 13.—*A* and *B*. Separation of sternal attachments of diaphragm through a vertical incision over xiphoid and transverse section through xiphoid and substernal ligament. *C* and *D*. Relation of parts before and after operation. (Case 3.)

CASE REPORTS*

CASE 4.—W. M., 19-month-old male child, was referred to the University of California Hospital in 1937 at the age of 5 months because of an inspiratory stridor and funnel sternum. A pediatric consultation determined that the boy had a mild degree of rickets and malnutrition, for which he was accordingly treated with drisdol, carotene, dicalcium phosphate, orange juice, and was followed in the Well-Baby Clinic for the ensuing year. No surgical procedure was done at first entry. The child re-entered the hospital at the age of 17 months, but because of a cold, was not operated upon. At this time it was felt that the rickets was cured. He was readmitted Feb. 13, 1939, at the age of 19 months. Examination showed that the funnel chest was in the nature of a depression

*Cases 4 and 5, whose histories presented similar clinical findings to those of Case 3, were operated upon in an identical manner, with essentially the same results.

at the junction of the ensiform cartilage and the lower end of the body of the sternum. There was a very mild Harrison's sulcus or grooving of the rib margin. The inspiratory stridor was still present but not so marked as previously.

In the operating room, a laryngoscopy was done by Dr. Morrison with the patient under ether anesthesia. This showed a laxness of the false vocal cords which permitted them to fall toward the midline on inspiration, causing the stridor.

A small vertical incision was made over the lower end of the sternum, which was then separated from the xiphoid. Then, by blunt and sharp dissection, the diaphragmatic attachments were freed from the undersurface of the lower tip of the body of the sternum, allowing it to come upward. The small wound was closed with a few silk sutures to the skin. Recovery from operation was entirely uneventful, and the patient discharged several days later.

CASE 5.—F. H., a 5-year-old boy. About three years previously the mother first noted a definite retraction of the lower aspect of the sternum. There had been a mild progression of this defect. The child was first seen in the Pediatrics Clinic where examination showed a sternum depressed in most of its length and ribs curved inward to meet its lateral border. There was no demonstrable added retraction with inspirations. The only other finding of note in the general examination was an undescended right testicle.

CONCLUSIONS

1. Two patients with cases of fully developed pectus excavatum were successfully relieved by operation, and report is made of three patients developing pectus excavatum upon whom a palliative operation was performed.

2. The presence of a strong hereditary factor in patients showing the deformity of pectus excavatum is again pointed out. All three cases reported in detail herewith demonstrated this factor.

3. The force producing the depression is shown to be the diaphragm acting primarily in the anteroposterior direction through its attachments to the sternum.

4. Because of the attachment of the pericardium to the diaphragm, the heart tends to be fixed near the midline along with the shortening of the central tendon of the diaphragm.

5. The existence of a membranous structure beneath the sternum is pointed out, and it is suggested that the term substernal ligament be applied to it.

6. The necessity of sectioning the substernal ligament, both to secure permanent relief when operating for pectus excavatum and to allow for the full extension of the chest upon the abdomen, is stressed.

7. An operative technique for the relief of fully developed pectus excavatum is presented, which is relatively safe and which requires no traction apparatus to maintain the sternum in the elevated position.

8. An operative procedure which appears to be of value in limiting the progress of a developing case of pectus excavatum is described and its use in other cases suggested.

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DISCUSSION

DR. RICHARD H. MEADE, JR., Philadelphia, Pa.—Soon after I had the opportunity of reading Dr. Brown's abstract of his paper, a patient with jaundice came into the hospital in which I was working, and was found to have carcinoma of the pancreas. It was also seen that he had marked pectus excavatum. He was a large man, 65 years old, and was well enough to tell me something about his family history. His father had had the same condition. He had had two sons who had it and a grandnephew. One son had rowed on the crew in college and had had no symptoms whatsoever. The patient died in the course of several weeks from carcinoma. An autopsy was done, but unfortunately I was not present. The pathologist had been instructed ahead of time to very carefully observe the findings in regard to the substernal ligament. According to his report, there was no disturbance of this ligament.

Immediately following that, three other patients came into the same ward with pectus excavatum. Some weeks later it was learned that one of our junior internes also had one, but of no clinical significance. From him we learned that his father and other members of his family had the same condition.

I think Dr. Brown has made a real contribution, particularly in regard to the correction of the defect in infants. I was very keen, in this case to which I first referred, to get in touch with the youngster who had the condition and to have a chance to operate on him. I have had no chance to operate on any of these patients. I quote this particular one on which an autopsy was performed, not to contradict what Dr. Brown has said, but only to add to what has been said on the subject.

DR. A. LINCOLN BROWN, San Francisco, Calif.—I wish to thank Dr. Meade for his discussion and to add that we do not propose that every case of pectus excavatum be operated upon. These methods are merely suggested, having proved to be satisfactory procedures in our hands in suitably selected cases. As far as the infant is concerned, we know that certain of these conditions go on to a developed state where operation in adult life becomes necessary, and, if in the infant, a small procedure which takes only a few minutes can be done and which will prevent the full development of the condition in the adult, we believe that may be indicated. As far as operating upon the adults is concerned, we only feel that it is indicated when embarrassment of one form or another results from the conditions, or when a woman, in particular, may want to have the repair for esthetic purposes, but not in order for the surgeon to have a depressed sternum upon which to operate.*

*Since the presentation of this paper two more cases have been operated upon successfully. In an infant the simple type of operation was employed, while a 12-year-old boy required the radical procedure.

MALIGNANT TUMORS OF THE DIAPHRAGM

J. W. Gale, M.D., and S. R. Edwards, M.D.
Madison, Wis.

THE report and the discussion of an isolated case are unjustified unless they can add to our present-day knowledge of diagnosis and therapeusis. Primary tumor of the diaphragm is a pathologic rarity. Very few reports of such cases have appeared in the literature. Dalzell,[1] 1887, Gross,[2] 1911, Sauerbruch,[3] 1913, Van Nes,[4] 1921, Müller,[5] 1933, Kirschbaum,[6] 1935, and Perry and Smith,[7] 1939, have reported the only cases of primary malignancy arising in this organ (Table I). Clark,[8] 1887, Bonamy,[9] 1912, Burvill-Holmes and Brody,[10] 1932, and Soderlund,[11] 1937, have reported benign tumors arising in this area (Table II). Numerous other reports which have appeared concerning secondary tumors of the diaphragm have not been included.

CASE HISTORY

G. K. J., a 54-year-old Syrian male, was admitted to the State of Wisconsin General Hospital on June 6, 1938, complaining of pain in the right shoulder. Onset of illness was in 1934 with occasional brief sharp pains at the point of the right shoulder, which were independent of any motion. One extremely severe attack occurred in 1935 with pain radiating from the shoulder to the right upper quadrant and the precordium. Hypodermics of morphine were required for relief. Impression of the patient's physician was gall bladder disease, although roentgenograms of the stomach and gall bladder showed no abnormalities. A low-fat diet was taken for one year with some improvement. There was no recurrence of the severe attacks, but brief sharp pains in the right shoulder and cervical region continued with increasing frequency and severity, radiating down the right arm to the fingers.

History by systems included: Frequent frontal headaches for two years, failing vision for the past three years, increasing deafness in the left ear for four years, slight dyspnea on exertion, palpitation on excitement, flatulence, intolerance to fatty foods, chronic constipation requiring use of magnesium sulfate, nocturia four to ten times, difficulty in starting urinary stream, increasing agitation on excitement, financial worries and periods of mental depression, loss of weight from 188 to 156 pounds in the past five years, large alcoholic intake up to 1933.

Past History.—The patient immigrated to the United States in 1900. He had been a merchant, a jeweler, and a tavern keeper. A gunshot wound of the left hand required amputation of the thumb and third finger in 1907. He underwent an appendectomy in 1912 and a bilateral inguinal herniorrhaphy in 1936.

Family history was not pertinent.

Physical examination showed a well-developed, well-nourished male about 50 years of age, not acutely ill. His skin was warm and dry; mucous membranes were of good color; speech was somewhat slurred. There were patchy alopecia, early

Read before The Twenty-Second Annual Meeting of The American Association for Thoracic Surgery, Los Angeles, Calif., July 5, 6, 7, 1939.
From the Departments of Surgery and Medicine, University of Wisconsin, Madison.

TABLE I

MALIGNANT TUMORS OF THE DIAPHRAGM

AUTHOR	TYPE OF TUMOR	SYMPTOMS	REMARKS
1. Dalzell (1887)	Round cell sarcoma, right side	None referable to tumor.	Female, aged 42 years. Died three weeks following fracture of femur. Metastatic lesion at site of fracture and in skull. (Autopsy.)
2. Gross (1911)	Fibrosarcoma, left side	For 2 months patient noted a small tumor mass under the left costal margin. Pleuritic-like pain.	Male, aged 30 years. Tumor 14.5 × 13.8 cm. Resected tumor with a portion of diaphragm. Patient recovered from the operation. Discharged on the 19th day. Death 7 months later of recurrence.
3. Sauerbruch (1913)	Fibromyosarcoma, left side	Patient had gastrointestinal symptoms.	Female, aged 43 years. Tumor along left costal margin appeared on inspiration and disappeared on expiration. Not diagnosed before operation but thought to be part of spleen. Removed. (Recovery.)
4. Van Nes (1921)	Fibrosarcoma, left side	Pain in left chest, dyspnea, and cyanosis.	Male, aged 65 years. At autopsy tumor size of child's head arising from a pedicle the size of the thumb attached to diaphragm. (Autopsy.)
5. Müller (1933)	Myoblastic sarcoma, right side	None recorded.	Female, aged 45 years. Tumor 10 × 7 × 4 cm. attached to the central tendon by a pedicle 4 cm. in length. Tumor was lobulated. (Autopsy.)
6. Kirschbaum (1935)	Undifferentiated myosarcoma resembling an immature rhabdomyosarcoma, right side	Symptoms of 8½ months. Pain in back and down right leg, weight loss, hemoptysis, sticking pain in left chest, cough.	Male, aged 47 years. Multiple metastases in right and left lungs. Large irregular tumor of diaphragm invading lung and liver. (Autopsy.)
7. Kirschbaum	Leiomyosarcoma, left side	Noted lump size of almond in the left upper quadrant 3 months before admission. Increased rapidly to the size of a fetal head, was fixed and nodular. Bloody pleural effusion was present.	Male, aged 58 years. Tumor 18 × 16 × 13 cm. fixed to the diaphragm and to the inner surface of the body of the sternum and projected into the left pleural cavity. Surface nodular. (Autopsy.)
8. Perry and Smith (1939)	Rhabdomyosarcoma, right side	Pain at right costal margin 2 months after injury to chest. Painful tumor mass. Cough. Loss of weight and strength.	Male, negro, aged 14 years. Right chest unduly prominent. Nodular swellings intimately attached to ribs on right. Tumor tissue infiltrated subcutaneously on the right side of the chest. Nodular masses in the right axilla. Tumor also encircled the diaphragmatic orifice of the vena cava. (Autopsy.)

TABLE II

BENIGN TUMORS OF THE DIAPHRAGM

AUTHOR	TYPE OF TUMOR	SYMPTOMS	REMARKS
1. Clark (1887)	Lipoma, right side	None.	Discovered at autopsy.
2. Bonamy (1912)	Multiple fibromyoma, right side	Had noted a swelling in the right hypochondrium for several months. Otherwise well.	Female, aged 34 years. Operation with removal of one large tumor and four smaller ones, total weight 1200 gm. (Recovery.)
3. Burvill-Holmes and Brody (1932)	Angiofibroma, right side	None referable to tumor. History and clinical course typical of pulmonary tuberculosis.	Male, aged 50 years. Mass seen on x-ray. At death, autopsy showed tumor 12 × 6 × 5 cm. lying between the leaflets of the diaphragm. It had made a depression into the dome of the liver.
4. Soderlund (1937)	Lipoma, left side	First a severe cold; developed pain in region of 11th rib posteriorly which radiated anteriorly, was stabbing in character.	Female, aged 50 years. X-ray revealed tumor. Pneumothorax instituted, and tumor seen on thoracoscopy. Operation with removal. Tumor size of hen's egg. (Recovery.)

arteriosclerotic changes in the retinal arterioles, partial false dentures, some flattening of the right upper chest anteriorly, palpable pulsation in the suprasternal notch. The left cardiac border was 10 cm. from the midsternal line in the fifth interspace, and a soft systolic mitral murmur was heard. The heart was regular at 72 beats per minute, and blood pressure, 136/98. Appendectomy and bilateral inguinal herniorrhaphy scars were well healed. The liver was palpable 5 cm. below the right costal margin at the end of inspiration. There was slight tenderness to percussion over the liver, and the spleen was just palpable. Muscle strength in extremities was good; there was slight pain but no limitation of motion in right shoulder. The prostate was of normal size and consistency; residual urine was 50 c.c.

Laboratory studies revealed urine, not abnormal; hemoglobin, 15.6 gm.; red blood cells, 4,860,000; white blood cells, 10,700; neutrophiles, 67, lymphocytes, 25, monocytes, 3, eosinophiles, 5; fasting blood sugar, 84 mg.; nonprotein nitrogen, 38 mg.; basal metabolic rate, 2; blood and spinal serology negative; phenolsulphonephthalein excretion, 50 per cent in two hours.

Roentgenograms.—A chest film on June 9, 1938, showed a bony thorax slightly smaller on the right, the aorta elongated, lung fields clear except at the right base where there was a clear-cut, smooth, rounded mass. On fluoroscopy, it was seen to move with respiration, to occupy the central portion of the dome of the diaphragm, and the mass appeared to be an integral part of it. The impression was a tumor of the pleura involving the diaphragm, or a tumor of the liver.

A stereoscopic film of the right shoulder showed no abnormalities in the bones or the joint. Films of the cervical spine showed moderately advanced osteoarthritis.

No abnormalities were shown in kidney, ureter, and bladder films, gastrointestinal series, an oral cholecystogram, and stereoroentgenograms of the skull.

Progress.—Right pneumothorax to outline the mass further was attempted repeatedly and unsuccessfully due to a pleural symphysis. A film of the chest on July 18, 1938, showed slight but definite increase in the size of the mass in the

region of the right diaphragm. Pneumoperitoneum was established with injection of 500 c.c. of air. On fluoroscopy and in films showing the pneumoperitoneum, the mass seemed to be an integral part of the right diaphragm, rising above the liver, except at the lower edge which appeared to be adherent to the liver (Fig. 1).

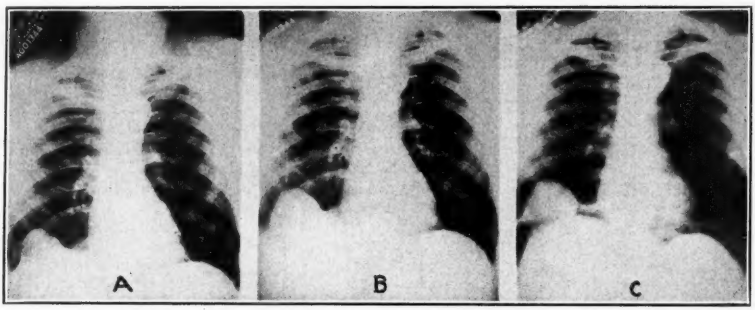

Fig. 1.—*A*, Roentgenogram showing size of tumor when first observed. *B*, Roentgenogram taken one month later showing the increase in size of the tumor. *C*, Roentgenogram showing the outline of the tumor after it has been brought into relief beneath the diaphragm through the institution of pneumoperitoneum.

Operation.—A right paravertebral incision was made over the ninth rib. The rib was resected subperiosteally, and the pleura was opened through the periosteal bed. The adherent lung was dissected free, and the tumor mass was found lying just medial to the dome of the diaphragm. An incision through the diaphragm lateral to the tumor found it adherent to and projecting into the dome of the liver. During exploration of the subphrenic space, the tumor separated from the liver, giving the impression that the attachment had occurred because of mechanical pressure and movement of the diaphragm rather than invasion into the liver substance. The tumor was removed by incising the diaphragm for a distance of 1 cm. around it. The bleeding from the liver was controlled with two mattress sutures. Careful palpation at this time failed to reveal any other tumor masses in the liver. The defect in the diaphragm was closed by imbricating the layers with chromic catgut reinforced by two rows of fascia lata sutures. The wound was closed in layers without drainage. The postoperative course was complicated by the development of an empyema. This was drained by rib resection, following which convalescence was uneventful.

The *gross specimen* showed a spherical tumor 3.5 cm. in diameter, extending above and below the diaphragm. The portion lying above was slightly larger. It was grayish in color. The muscle fibers of the diaphragm at the periphery were intact, but, as they passed over the apex of the tumor, they were separated and thinned, finally disappearing, and displaced by tumor tissue. The lower half was soft and covered by a thin layer of liver cells. Cutting through the mass revealed definite resistance. The upper half was gray, fibrous, and resembled dense connective tissue arranged in bundles. The lower half appeared necrotic and was semisolid. (Figs. 2 and 3.)

The *microscopic examination* by Dr. W. D. Stovall showed the following: A mass composed of one large area which had undergone almost complete necrosis. In this area there were a few islands of cells which formed collars around blood vessels. This part of the mass was the one which was imbedded in the liver. It was completely surrounded by a thin fibrous tissue capsule. There was no liver tissue attached to it. The impression was that it may have been enucleated from a depression

in the liver. This portion of the fibrous tissue capsule showed many collections of lymphocytes, endothelial cells, plasma cells, and only occasionally a polymorphonuclear leucocyte. The capsule was well supplied with blood vessels, and in places it was invaded by the cells of the neoplasm; but they did not appear to break through the lower border. This fibrous tissue band or capsule merged on one side of the mass with bands of muscle fibers of the diaphragm. These muscle fibers covering the upper portion were invaded by the neoplasm. At one edge the tumor cells were not covered by muscle or fibrous tissue. This gave the appearance that the tumor had been cut across and a portion left in the diaphragm. Following this gap, the muscle fibers again encased the growth. Above the large necrotic

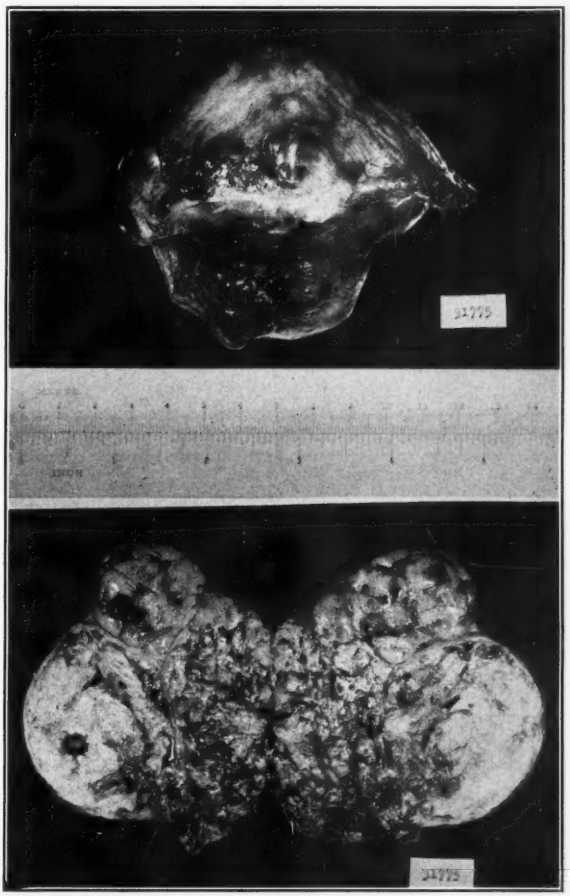

Fig. 2.—Photographs of gross specimen intact and after bisection in the longitudinal diameter, demonstrating the architecture as described in text.

mass previously described there were areas of necrosis. It was very vascular, areas being encountered which were filled with blood or blood serum. The tumor cells themselves appeared to form the walls of these spaces. There were no trabeculae coursing through the mass. The cells showed no particular arrange-

Fig. 3.—Photomicrograph (×160) shows perivascular arrangement of tumor cells. A large blood-filled space is seen in one area. Islands of tumor cells are seen in this space. The general architecture of the tumor is apparent in these sections.

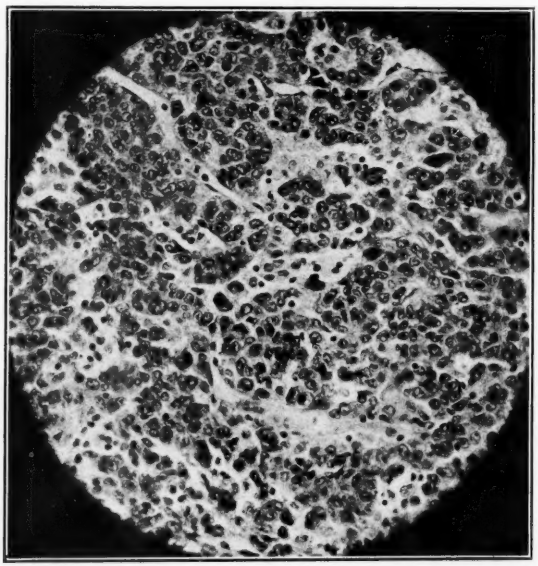

Fig. 4.—Photomicrograph (×350) shows detached architecture of tumor. The cells show marked variation in size and staining reaction. Most of the cells have oval to round nuclei with prominent nucleoli. The cytoplasm of the cells is quite granular. The architecture in this area suggests a hepatoma.

ment. In areas where a few fibrous bands coursed, they occurred in alveolar groups. Where there was much necrosis, the cells occurred in groups around blood vessels, giving the appearance that has been described in tumors diagnosed as peritheliomas. The cells themselves showed some pleomorphism, but throughout showed a fair degree of uniformity in size and staining reaction. There was, of course, some hyperchromatism of the nuclei. The nuclei were spherical, slightly elongated, and contained from one to several prominent nucleoli and very fine clumps of chromatin. The cytoplasm stained basophilic and, in some cases, took the eosin and appeared quite granular. Almost everywhere the cell borders were indistinct, but there were areas where the borders were clear-cut. It was very rare that an exceptionally large cell was seen.

This appeared to be a malignant neoplasm. Its vascularity, lack of organoid arrangement, grouping cells around blood vessels, and other characteristics lead us to believe that the tumor was a primary endothelial sarcoma. Because of the rarity of this tumor we have asked for opinions from a number of other pathologists. We have received from them the following diagnoses: adenocarcinoma with no reference as to origin; primary adenocarcinoma of the liver, malignancy grade IV; epithelial cell tumor probably arising in the liver; and primary hepatoma of moderate malignancy, arising in all probability from an isolated lobule of embryonal liver. (Figs. 2 and 3.)

DISCUSSION

There are no definite signs and symptoms associated with tumor of the diaphragm. Only four of the eleven cases, including our own, complained of pain. Three noted the presence of a mass on the involved side, five had no symptoms whatsoever, and two had secondary involvement.

Although the x-ray is useful and permits the visualization of the tumor, one is still in doubt as to whether it lies in the pulmonary tissue, liver, peritoneal cavity, or the diaphragm. A careful history will help rule out pulmonary involvement, but with an advanced lesion associated with a pleural effusion, it may serve to complicate the picture. Artificial pneumothorax, if possible, will separate the lung from the diaphragm, and in certain instances, as described by Soderlund, allow thoracoscopic examination with visualization of the tumor. Pneumoperitoneum, as employed by Binney, will bring the lower surface of the diaphragm into relief and give the necessary information below. In our case, attempts at pneumothorax were unsuccessful, but pneumoperitoneum showed very clearly that the tumor was involving the diaphragm and that this organ was not adherent to the right lobe of the liver except at the site of the tumor. Fluoroscopic examination showed the tumor moving synchronously with the diaphragm. In this case the absence of pulmonary symptoms, negative bronchoscopic examination, and gastrointestinal series, combined with the presence of a new, rapidly enlarging growth lying in the region of the diaphragm which was separated from the underlying liver by pneumoperitoneum, warranted a clinical diagnosis of malignant tumor of the diaphragm.

This, like the previously described tumors of the diaphragm, we believe to be of connective tissue origin.

Follow-up studies carried out six and nine months postoperatively have failed to show evidence of malignancy in any other part of the body. The patient remains well and free from clinical signs of recurrence.

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DISCUSSION

DR. ETHAN FLAGG BUTLER, Ithaca, N. Y.—I wish to report briefly a benign, intrathoracic cyst, arising from the upper surface of the left diaphragm. The patient was a 34-year-old woman. There were no symptoms. Roentgenologic evidence of the cyst was discovered during a routine chest examination. As there was evidence of increase in size over a series of examinations, operation was advised. The cyst was easily removed. It was apparently benign. Microscopic examination showed it to be lined by a single layer of actively secreting cuboidal cells. The patient made a satisfactory recovery.

DR. JEROME R. HEAD, Chicago, Ill.—I have no primary tumors of the diaphragm to report, but I would like to say a word or two about the repair of the diaphragm after the removal of tumors which affect it. During the past year I have operated upon a case of peripheral carcinoma of the right lower lobe. At operation this was found to be attached to the diaphragm and to the lower costal wall. Exploration revealed that it had not penetrated through the diaphragm sufficiently to involve the liver. A segment of the chest wall was removed and also the larger part of the dome of the right diaphragm. The defect in the diaphragm was too large to permit approximation of the edges. The cut edges of the diaphragm were attached to the liver by interrupted sutures, leaving the upper surface of the liver exposed in the pleural cavity. Following the operation the patient had no trouble and is well eight months after the operation.

DR. FRANK B. BERRY, New York, N. Y.—I enjoyed this paper exceedingly, but wondered if perhaps a preliminary phrenicectomy might not make the operative procedure and the repair of the diaphragm afterward somewhat easier.

Dr. Otto Pickhardt reported a similar case of pericardial-diaphragmatic cyst before the New York Surgical Society two years ago. I had an identical case. The cysts are very easy to remove and occur at the juncture of the pericardium and the diaphragm. The cases that Dr. Pickhardt was able to find in the literature were of similar nature.

DR. THOMAS J. KINSELLA, Minneapolis, Minn.—First of all I wish to congratulate Dr. Gale upon his presentation. I should like to add to those already presented a case report of what is apparently a primary benign tumor of the diaphragm. A woman, aged 62 years, was referred to me with a provisional diagnosis of carcinoma of the lung. She presented no pulmonary symptoms, but did complain of upper abdominal pain, nausea, and vomiting, a loss of 20 pounds in weight, and a local tumor mass between the sixth and seventh ribs in the right anterior axillary line. Further study proved that the pain, nausea, and vomiting were caused by a ureteral stone which was extracted from below. Examination revealed a large irregular tumor mass in the anterior portion of the right lower chest. Over it a loud bruit could be heard and a small thrill palpated. A very vascular tumor, probably malignant, was suspected.

Exploratory operation revealed a large, firm, nodular tumor, apparently arising from the anterior portion of the right hemidiaphragm with two-thirds of its mass above and one-third below the diaphragm. One projecting nodule had forced itself between the sixth and seventh ribs but did not infiltrate the chest wall. The surface of the tumor mass was covered with large blood vessels arising from the diaphragm. The tumor, with its diaphragmatic attachments, was excised, leaving a large defect closed by imbrication and suture to the chest wall.

The excised mass, over 2 pounds in weight, was a benign fibromyoma grossly resembling a uterine fibroid. The patient made a complete recovery complicated only by a local empyema which healed rapidly following external drainage.

DR. JOSEPH W. GALE, Madison, Wis.—I am glad to learn that Dr. Kinsella has encountered one of these very rare benign tumors of the diaphragm. His report adds to the very small list of cases and brings the total number to five. Dr. Edwards and I are not entirely sure that our case is one of primary malignant tumor of the diaphragm. We have reported it as such because the pathologists who saw the sections could not agree. Our own pathologist feels definitely that it is a primary tumor of the diaphragm. Two other pathologists who examined the sections were unwilling to hazard an opinion as to the source of the tumor. We feel justified in reporting this case and feel that the diagnosis will have to remain as reported until further examination can disprove our findings.

As to Dr. Berry's remarks concerning a preliminary phrenicotomy, I did that at the time of operation. The diaphragm is now moving again, and there is very little resultant deformity. The tumor, as stated in the paper, was 3½ inches in diameter, and it was surprising to note the ease with which the relaxed peripheral muscle fibers could be brought in apposition to cover the defect left from the removal of the tumor. Fascia lata sutures were used to unite these muscle fibers, and we were afraid that they would slough away when the patient developed a complicating empyema during his convalescence. This, however, was not the case because the empyema healed rapidly, and there was no evidence of slough of these sutures.

OBSERVATIONS ON THE EFFECT OF AMYL NITRITE ON THE BRONCHIAL TREE*

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INTRODUCTION

CLINICIANS have long used nitrites to relieve the dyspnea of bronchial asthma; sometimes amyl nitrite has been used, but more often one of the many asthma powders which liberate nitrites on combustion. Thomas Fraser, of Edinburgh, writing in 1887, tells of a series of clinical observations which he and his assistants made in cases of asthma. He gave his patients amyl nitrite to inhale during the attacks and auscultated the chest during the experiment. He says: "When the observation was made (August, 1880) she was sitting up in bed suffering from great breathlessness. The pulse was 100, and the respirations 28 per minute. On auscultating the front of the chest, it was found that expiration was markedly prolonged, and that both inspiration and expiration were accompanied with cooing, whistling, and creaking râles, and with occasional medium crepitations.

"At 1:55 P.M. she began to inhale 10 minims of nitrite of amyl placed on blotting paper at the bottom of a small glass tumbler, and she continued inhaling for about one minute and fifty seconds, the chest being continuously auscultated during the observations.

"At 1:56½ P.M. the face was flushed, and the pulse was 120 per minute. At 1:57 P.M. the cooing, whistling, and creaking râles had entirely disappeared, and the patient spontaneously remarked that her breathing was easier and that the sensation of tightness has disappeared from the chest.

"At 2:4 P.M. the breathing was difficult, and the râles as loud and continuous as they had been before the inhalation. From 2:6 P.M. to 2:7 P.M. she again inhaled nitrite of amyl. At 2:6½ P.M. the face was flushed. At 2:6¾ the flushing had increased, the râles in the chest had entirely disappeared, and the patient stated that the breathing was perfectly easy."

And so Fraser goes on describing how a whiff of amyl nitrite relieved his patient's dyspnea for a few minutes at a time, and he observes that in each instance the adventitious sounds disappeared from the chest on auscultation. This he believed to be due to dilatation of the bronchial muscle. In conclusion, he shows that the most pro-

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longed relief from dyspnea is obtained by giving the nitrite by mouth, and he suggests that "the facts that have been stated seem to justify the assertion that their administration in this manner (nitrites by mouth) in asthmatic dyspnea or orthopnea is entitled to rank as one of the most valuable of the applications of pharmacology to the treatment of disease, an application as valuable as that in the painful angina of aortic disease, to which nitrites are at present almost restricted."

There has been no further demonstration of the action of nitrites on bronchial muscle since this work of Fraser. It is true that nitrites were frequently used in asthma, but with the increasing use of adrenaline they have sometimes been almost forgotten. A well-known textbook of pharmacology dismisses the action of amyl nitrite on bronchial muscle with the words: "bronchial muscle is apparently relaxed, for relief is given in asthma." It was considered that an attempt should be made to demonstrate this action of a nitrite on bronchial muscle; this work is the result of that attempt.

METHODS

The first requirement of such an experiment is to have a ready method for comparing the caliber changes in the bronchi. Ellis and Livingston made use of a rubber balloon which was introduced through a bronchoscope and connected to a tambour. This is a direct method, but it is not very satisfactory in practice. Several observers have made use of an easier indirect method, which consists of making lipiodol injections of the bronchial tree and taking roentgenograms with the patient and apparatus in constant positions, so that any visible change in a series of films is due to alteration of the condition of the bronchi. In this way Heinbecker successfully demonstrated the changes in caliber in the dog's bronchi during the different phases of respiration, Francis investigated bronchial innervation in cats, and Anderson has recently studied the effect of adrenaline on asthmatic patients.

At first this may seem to be an ideal way of demonstrating caliber changes in the bronchi, and this is certainly the case when adrenaline is being studied. But when amyl nitrite is inhaled, it is possible that the lipiodol which produces a good bronchogram will interfere with the action of the amyl nitrite on the bronchi by so coating the bronchial tubes that the drug is not absorbed. This fear seems to have had little substance, judging by the results of these experiments. A more real difficulty presents itself in the case of asthmatics, who take lipiodol badly and cough so frequently during its instillation that unless some premedication, such as codeine, is given, the roentgenograms are valueless. Singer demonstrated by bronchograms the marked constriction that occurs during an asthmatic attack, his patient having an attack during the routine instillation of the oil for therapeutic purposes. Owing to this technical difficulty, very few of the bronchograms made on asthmatic subjects were good enough to be included in this series. Preliminary experiments were done on dogs, and later the work was extended to patients who were receiving lipiodol for diagnostic reasons in the Chest Service of the hospital.

EXPERIMENTS ON DOGS

Technique.—The animals were anesthetized with intravenous nembutal (1 c.c. per 2.5 kg. body weight) and a gum elastic catheter was passed into the trachea by direct vision. This is a simple maneuver in the dog, the larynx being easily exposed

by traction on the tongue. Lipiodol, warmed slightly, was run down the catheter and the animal tilted so that good filling of the bronchial tree on one side was obtained. At first both lungs were filled, but in later experiments it was decided to fill only one lung at a time for two reasons: first, because in the dog the thorax is so deep in a dorsoventral direction that the best pictures of the bronchial tree are obtained in lateral views, which results in overlapping of the two lungs on the film; and second, by filling only one side at a time, the same dog could be used again the next day if necessary, the opposite side being injected.

Lateral x-rays were taken at the end of expiration. The dog was secured in a constant position by a cradle, and the exposure of the film was timed to be made during the pause in the respiratory act which occurs between the end of expiration and the beginning of another inspiration. In most cases, this could be done well enough by watching the respirations carefully, but in a few cases the respirations were so rapid that accurate exposures were impossible, and in these cases no attempt was made to secure them. After the first exposure had been made, the animal was given amyl nitrite ℥ x to inhale, a towel with two crushed spirets being held over the mouth. One minute later a second exposure was made, again at the end of expiration, the x-ray tube and the animal occupying positions identical with those during the first exposure. In the same way pictures were taken after the intravenous injection of adrenaline and pilocarpin. Ten experiments were performed, but the films were good enough to study in only four of these, the failures being due to insufficient lipiodol in the bronchi or to respirations so rapid that accurate timing of the exposure was impossible.

Conclusions From Experiments on Dogs.—Dilatation of the bronchi has not been obtained in any of these cases. On the other hand, constriction has been produced by pilocarpin. In this connection the factor of the anesthetic must be duly weighed, as it certainly produces some relaxation of the bronchial muscle, and this would obviously diminish the degree of additional relaxation obtainable by inhalation of amyl nitrite. At the end of expiration, the bronchi are normally in a state of constriction, whereas at the end of inspiration they are dilated (Heinbecker). It, therefore, follows that the action of any bronchial dilator should be most apparent if the x-ray exposure is made at the end of expiration. In these animals both amyl nitrite and adrenaline were without effect. In the case of the former, it is possible that the lipiodol prevented much of the drug reaching the bronchial muscle, but in the latter case no such objection could be raised. The experiments, therefore, failed to show that amyl nitrite or adrenaline had any action on the smooth muscle of the bronchi in the anesthetized dog.

OBSERVATIONS IN MAN

Technique.—In man, controlled experiments are necessarily difficult, and in this study it was impossible to use the same technique in every case. Most cases observed were patients who received lipiodol by the aspiration method for diagnostic purposes; a few of these required local pharyngeal anesthesia, 1 per cent pontocaine being used, but in many cases no anesthetic was needed. Other cases were bronchoscoped under light avertin anesthesia and lipiodol injected directly through an endotracheal catheter after the bronchoscopy was finished. Finally, there were a few "controls," patients with no known pulmonary lesions, who consented to be examined by this method.

The aspiration method of giving lipiodol is satisfactory without anesthesia in about 85 per cent of adults, and with local anesthesia in a further 10 per cent. The patient is simply asked to breathe quietly through the open mouth and to avoid swallowing and coughing as much as possible. The tongue is then pulled well forward by the operator, who slowly drops warm lipiodol from a syringe down over the back of the tongue into the larynx. With a little practice, this method has been found most satisfactory, the patient aspirating the warm oil easily, provided that deglutition is prevented by keeping the tongue well forward.

As soon as a satisfactory bronchogram was obtained, the patient lay supine on a trolley and an overhead anteroposterior film of the chest was taken, the breath being held in maximal inspiration. This phase of respiration was chosen because it gives the best picture of the lung fields and is easily maintained by a conscious patient; furthermore, any dilator effect observed on the bronchi in maximal inspiration would certainly show a more marked effect in expiration, although the converse would not be true. In a few cases exposures were made in expiration. A 4-foot chest film was taken in all cases with both the patient and x-ray tube remaining in identically the same positions throughout the experiment. In the first few cases the patients stood upright for the x-ray, but this was soon abandoned owing to the difficulty of administering the amyl nitrite in that position and the dizziness experienced by the patient.

After the first exposure was obtained, the blood pressure in the right brachial artery was determined. This unfortunately was omitted in the earlier cases. Then amyl nitrite ℥ v or ℥ x, usually the latter, was given by inhalation on a piece of gauze. In each case the patient was requested to take twelve slow, deep breaths, and after the last inhalation, to hold the breath while the second exposure was made. About 90 per cent of the patients tolerated this well and experienced no unpleasantness except for the transient "light-headedness" and occasionally slight dizziness. These symptoms always disappeared within two or three minutes. A few patients were unable to take twelve inhalations, but on subsequent inquiry the reason most often appeared to be that they had not understood the nature of the test, which had always been carefully explained, and thought that they were being anesthetized! Immediately after the cessation of inhalation of amyl nitrite, the brachial blood pressure was determined again. The greatest care was taken that movement or coughing did not occur between the exposures.

Amyl nitrite was the only drug studied; it is so easily given and so quickly eliminated that patients could walk home within ten minutes of the experiment. Adrenaline was not used, because it does not have these advantages. There were no lasting unpleasant effects attributable to inhalation of the amyl nitrite; headache when produced seldom persisted for half an hour.

OBSERVATIONS

There are several questions which naturally arise in interpreting the results of these experiments:

1. Is amyl nitrite a bronchodilator?
2. How much is its action impeded by lipiodol?
3. Has it any selective action on the terminal bronchi in preference to the larger bronchi?
4. Is there any relation between its action on the bronchi and its action on the cardiovascular system?
5. How much do pathologic changes in the lung modify its action?
6. And lastly, has it any diagnostic value, and of what use is it in therapeutics?

Twenty-six cases have been analyzed. Although in four of them the bronchograms were not good enough to allow the bronchi to be measured, yet they are included in the series because careful observations showed no gross change in the appearances of the bronchi. Naturally only the larger bronchi can be measured and their widths compared; if these are not filled, an impression of the comparative sizes of terminal bronchi can be obtained, although not exact. Two of these four cases were colored men who had no pulmonary lesion; neither of them cooperated well in the test, so some doubt must be placed in the experiments. Of the other two, one was a case of bronchiogenic carcinoma, and the other, a case of bronchiectasis in a child who was under avertin anesthesia. (Table I, Cases 1-4.)

Next come six cases (5-10) which showed no dilatation except in Case 10, in which there was slight dilatation in one lobe. In these cases, accurate measurements were made of corresponding bronchi on the films in each case. Five of these patients were over 45 years of age, two of them with cases of bronchiogenic carcinoma, one lung abscess, one emphysema, and one with no pulmonary lesion. The other case (5) was a young girl with bronchiectasis.

TABLE I

CASE LIST

CASE NO.	SEX	AGE	CHEST LESION	TOTAL DILATATION	RELATIVE DILATATION	
					IN LARGE BRONCHI	IN SMALL BRONCHI
1	♂	50	None	None	--	--
2	♂	28	None	None	--	--
3	♂	55	Bronchiogenic Carcinoma	None	--	--
4	♂	14	Bronchiectasis (avertin anesthesia)	None	--	--
5	♀	15	Bronchiectasis	None	--	--
6	♀	56	Bronchiogenic Carcinoma	None	--	--
7	♂	45	Bronchiogenic Carcinoma	None	--	--
8	♀	50	Healed Lung Abscess	None	--	--
9	♂	46	Emphysema	None	--	--
10	♂	52	None	Slight	--	--
11	♀	8	Bronchiectasis	+	21%	18%
12	♂	20	Congenital Cystic Lung	+33%		
13	♂	30	Bronchiectasis	+22%		
14	♀	46	Asthma (codeine gr. i)	+17%		
15	♀	22	Chronic Bronchitis	+	0	30%
16	♂	26	Bronchiectasis	+	0	33%
17	♀	25	Chronic Bronchitis	+		
18	♀	54	Hemoptysis (origin?)	+	12%	21%
19	♂	53	Bronchiogenic Carcinoma	+	15%	27%
20	♂	53	Bronchiogenic Carcinoma	+	10%	25%
21	♂	48	Chronic Bronchitis	+	13%	18%
22	♀	30	Asthma	+78%		
23	♂	46	None	+21%		
24	♂	34	None	+32%		
25	♂	23	None	+17%		
26	♀	21	Bronchiectasis	+22%		

The remaining cases (11-26) show bronchial dilatation after amyl nitrite. In each case the bronchi were measured on the films, and in some cases, prints of these films are shown. The regions studied were chosen, not because they showed the most dilatation, but because in them there was the greatest clarity of the bronchial pattern with a minimal degree of overlapping of the bronchi.

Not every case showed uniform dilatation of the bronchial tree; in fact in some cases, notably Nos. 15, 16, and 17, the dilatation, though marked in the secondary bronchi, was absent in the main bronchi. These three cases were those of young adults with chronic bronchitis, one of them also suffering from bronchiectasis. On the other hand Cases 11, 18, 19, 20, and 21 show dilatation in all the bronchi.

It is a little difficult to compare the results obtained in all these cases, but although the series is small, some deductions can be drawn from a detailed study. Cases 11, 15, and 17 must be eliminated from this list, because in these cases the x-rays were taken at the end of expiration, and so more dilatation would naturally be expected. Actually only a rather slightly higher than average dilatation resulted—certainly not as much as the best that followed in some of the other cases.

In Case 22, measurements of the diameters of six bronchi were taken. Five of these showed dilatation. In this case it was not possible to measure the main bronchi, but only their branches. If the total dilatation resulting in the five bronchi measured is expressed as a percentage of the sum of the diameters of those bronchi, then a figure is obtained—the percentage dilatation—which can be compared with that occurring in other cases. Only the bronchi which actually dilate are taken into account, because in some cases the main bronchi are well-seen and measured, whereas in other cases they cannot be measured. Should they dilate in neither case, then the percentage dilatation in the former would appear lower than in the latter if their diameter were included in the analysis. Therefore, a bronchus is only included when actual dilatation occurs in it. The formula used to obtain the degree of dilatation is this:

$$\text{Degree of dilatation} = \frac{\text{Total dilatation in mm.} \times 100\%}{\text{Sum of diameters of bronchi dilated in mm.}}$$

Arranging the cases in order of decreasing percentage of dilatation, the list given in Table II resulted.

With one exception, all the younger patients showed greater dilatation; five older patients showed no dilatation at all. The dilatation in one case of asthma is striking, and this patient was greatly relieved after the inhalation of amyl nitrite during attacks. The other case of asthma had 1 gr. of codeine before the experiment to depress the cough reflex. These particular cases are rather difficult to study in this way because, as a rule, they tolerate lipiodol poorly unless they receive some

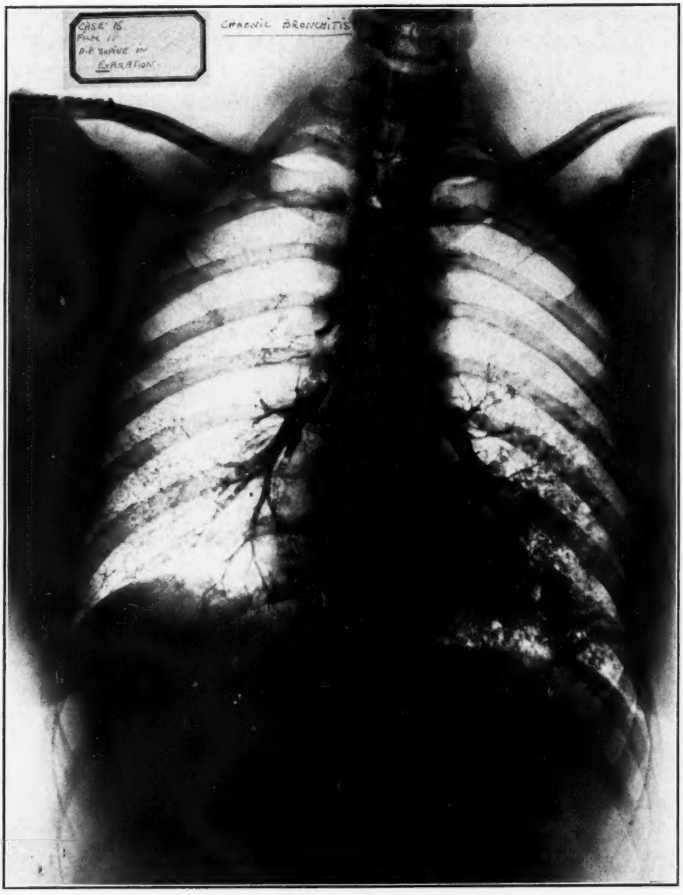

Fig. 1*A*.

CASE 15.—M. C., white female, aged 22 years, chronic bronchitis. Lipiodol administered by aspiration Oct. 4, 1937. X-rays, F. 76691, 76692. Film 1 (Fig. 1*A*): anteroposterior supine position, in maximal expiration. Blood pressure, 120/80. Film 2 (Fig. 1*B*): anteroposterior supine position, in maximal expiration after administration of amyl nitrate, ♏ x. Well tolerated. Blood pressure 150/90. Note dilatation of small bronchioles.

MEASUREMENTS IN MILLIMETERS

	a*	b	c	d	e	f	g	h	i
Film 1	13	12	12	5	3	2.5	3	3.5	3
Film 2	13	12	12	5	4.5	4	4	4.5	4

*See Fig. 1*C*.

Summary.—Dilatation in the smaller bronchi, but not in the large tubes. Relative dilatation: Large tubes, 0; small tubes, 30 per cent.

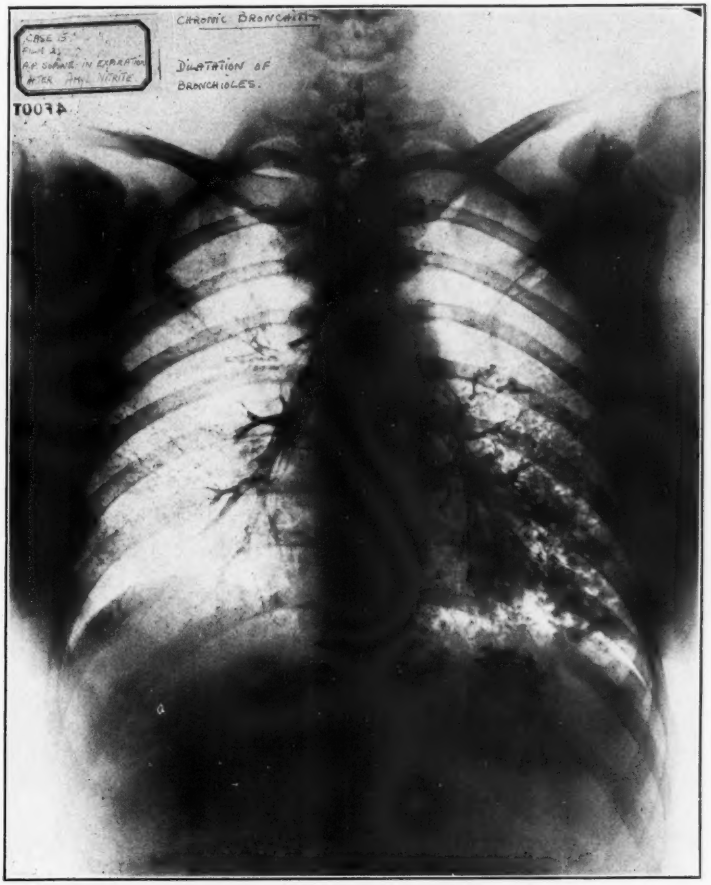

Fig. 1*B*.

EXPLANATION OF CHARTS

The tracings which supplement the photographs were made directly from the x-ray films, and copies of these were made. They are not designed to be any more than a record of the bronchi which were measured on the original film. Corresponding points were always measured on the two films, and this accounts for so few measurements in some cases because, in these, either overlapping or incomplete filling of the bronchi made their identification difficult. In some cases the lengths were measured as well as the widths, but the former varied but little and interest was centered more in changes in diameter. The degree of dilatation is recorded in the legends under the illustrations.

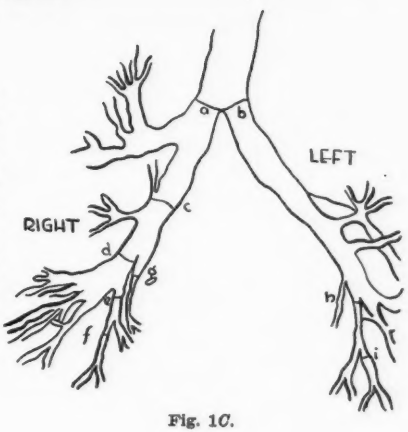

Fig. 1*C*.

Fig. 2*A*.

CASE 16.—R. E., white male, aged 26 years, bronchiectasis of the lower lobe of the right lung. Lipiodol administered by aspiration Oct. 13, 1937. Local anesthetic, 1 per cent pontocaine. X-rays, F. 76932, 76934. Film 1 (Fig. 2*A*): right posterior oblique position, in maximal inspiration. Blood pressure, 130/80. Film 2 (Fig. 2*B*): right posterior oblique position, in maximal inspiration after administration of amyl nitrate, ℥ x. Well tolerated. Blood pressure, 140/85.

MEASUREMENTS IN MILLIMETERS

	a*	b	c	d	e	f
Film 1	16	10	8	2.5	6	3.5
Film 2	16	10	10	3.5	8.5	4.5

*See Fig. 2*C*.

Summary.—Dilatation, not in stem bronchi, but in branches. No change in bronchiectasis. Total dilatation, 33 per cent. Relative dilatation: Large tubes, 0; small tubes, 33 per cent.

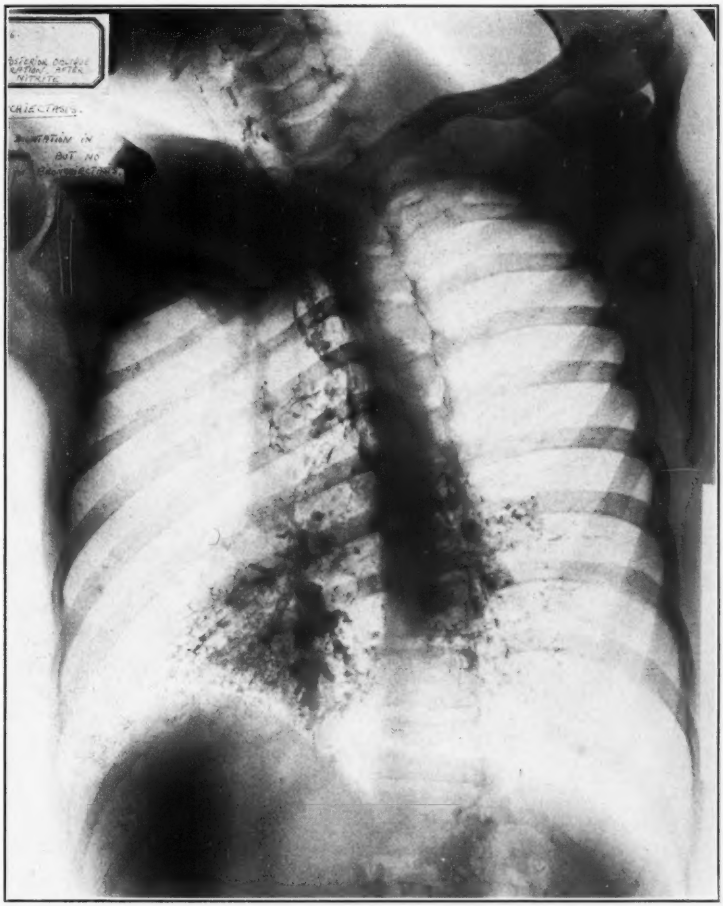

Fig. 2B.

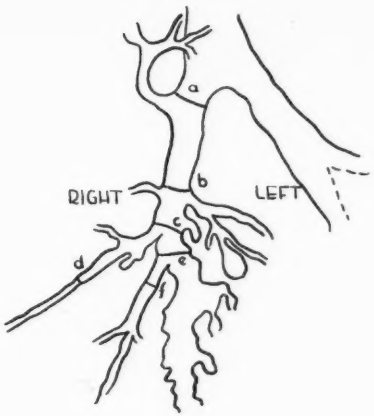

Fig. 2C.

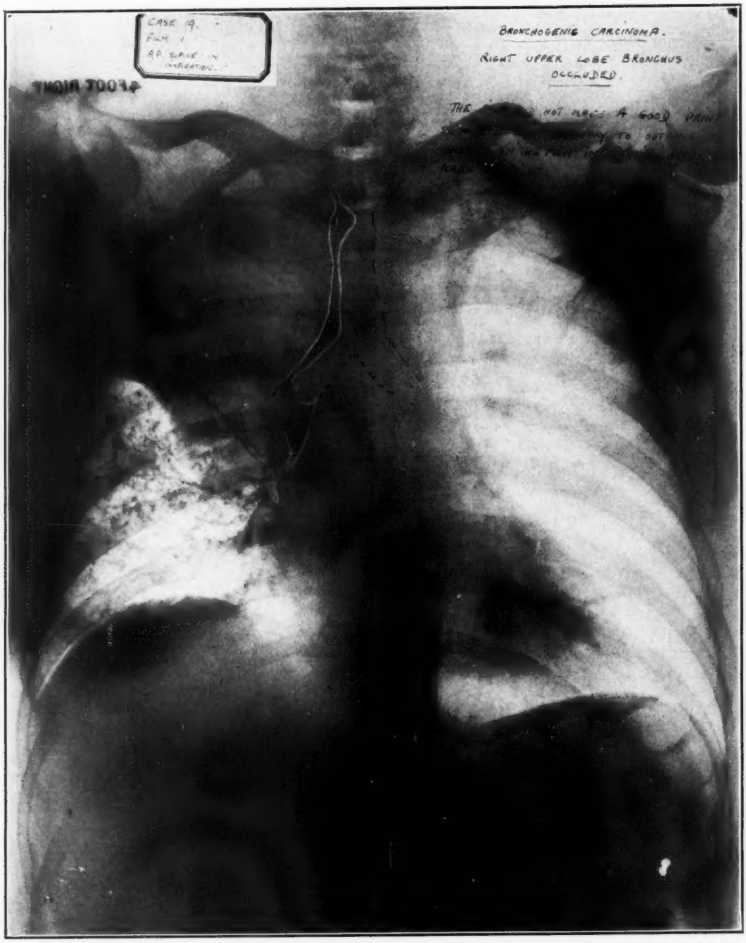

Fig. 3*A*.

CASE 19.—L. G., white male, aged 53 years, carcinoma of upper lobe of right lung. Lipiodol administered by aspiration Sept. 24, 1937. X-rays, F. 76383, 76392, 76391, 76390. Film 1 (Fig. 3*A*): anteroposterior supine position, in maximal inspiration. Blood pressure, 145/90. Film 2: right lateral position, in maximal inspiration. Film 3: right lateral position, in maximal inspiration after administration of amyl nitrate, ℿ x. Blood pressure, 145/90. Film 4 (Fig. 3*B*): anteroposterior supine position, in maximal inspiration after administration of second dose of amyl nitrate, ℿ v. Well tolerated. Blood pressure, 140/90.

MEASUREMENTS IN MILLIMETERS

	a*	b	c	d	e
Film 2	10	10	5	3	3
Film 3	12	11	6	4	4

*See Fig. 3*C*.

Fig. 3*B*.

Summary.—Dilatation. The most interesting observation in this case, however, is the improved filling in the upper lobe of the right lung which is occluded in Fig. 3*A*. Unfortunately the films are too dense to make good prints, but the upper lobe bronchus was pencilled in the film and this has been photographed. This is seen in Figs. 3*A* and 3*B*. Total dilatation, 19 per cent. Relative dilatation: large tubes, 15 per cent; small tubes, 27 per cent.

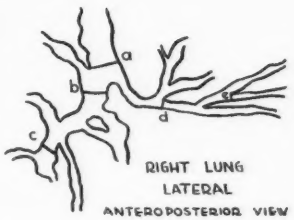

Fig. 3*C*.

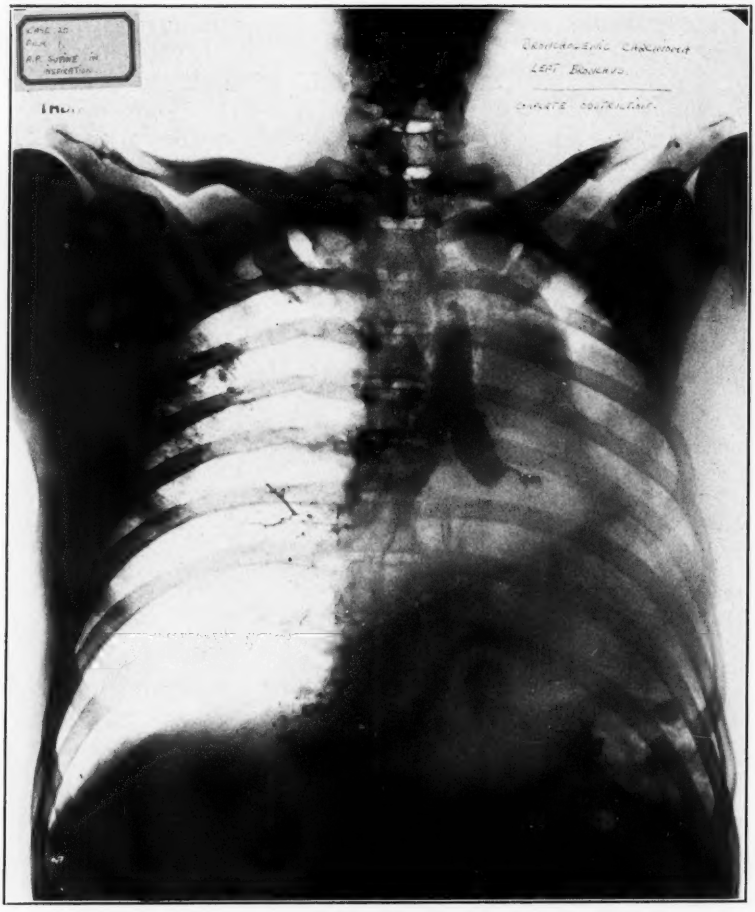

Fig. 4*A*.

Case 20.—E. G., white male, aged 53 years, carcinoma of left lung. Lipiodol administered by aspiration Oct. 23, 1937. X-rays, F. 77085, 77086. Film 1 (Fig. 4*A*): anteroposterior supine position, in maximal inspiration, without anesthesia. Blood pressure, 90/70. Film 2 (Fig. 4*B*): anteroposterior supine position, in maximal inspiration after administration of amyl nitrate, ℥ x. Well tolerated. Blood pressure, 90/70.

Measurements in Millimeters

	a*	b	c	d	e	f
Film 1	16.5	15	13.5	16	4	22
Film 2	18	16.5	16	17.5	5	24

*See Fig. 4*C*.

Summary.—Dilatation of all the bronchi outlined. There is also a little better filling of the obstructed left bronchus. The patient felt that the left lung filled out on deep inspiration and this appeared to be especially helped by the amyl nitrate. Total dilatation, 12 per cent. Relative dilatation: large tubes, 10 per cent; small tubes, 25 per cent.

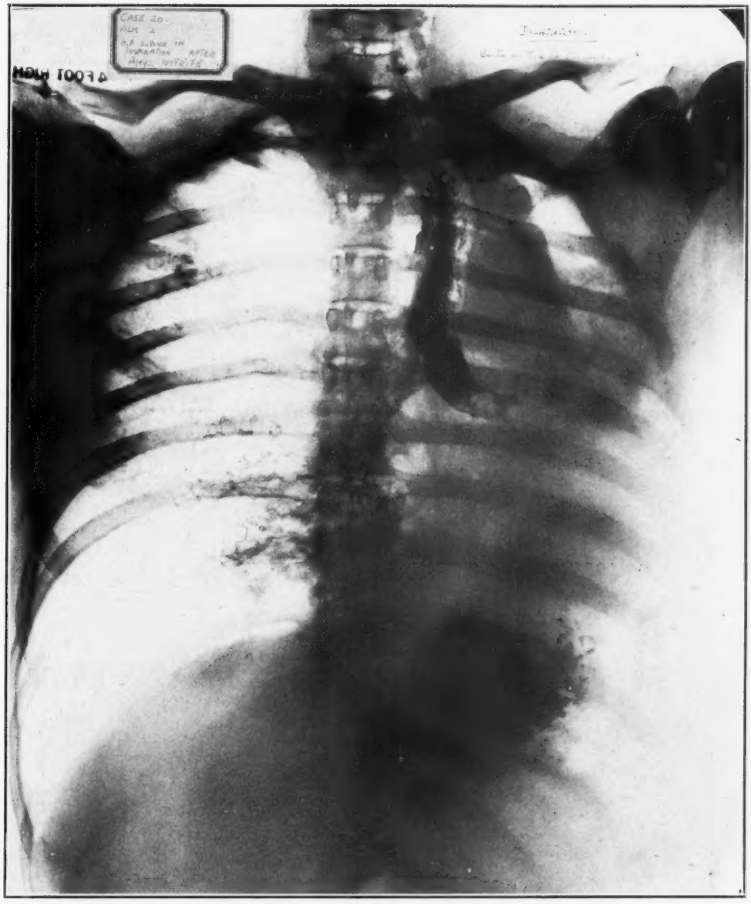

Fig. 4*B*.

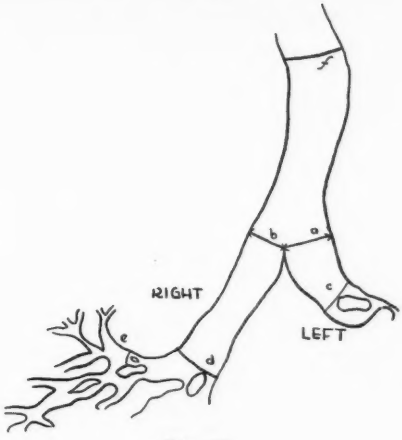

Fig. 4*C*.

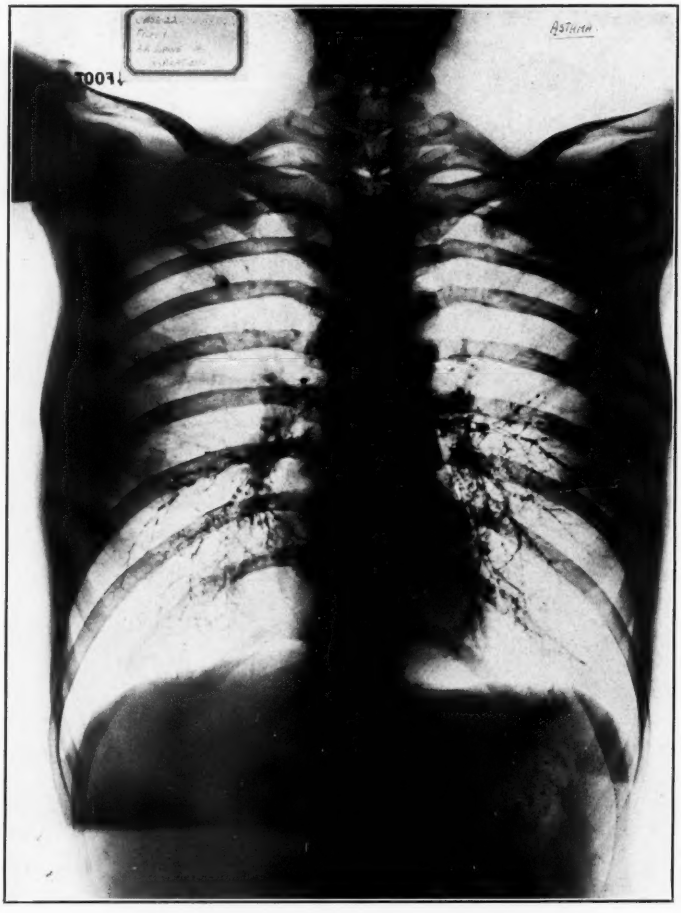

Fig. 5*A*.

CASE 22.—E. L., white female, aged 30 years, bronchial asthma. Lipiodol administered by aspiration Sept. 9, 1937. X-rays, F. 76159, 76160. Film 1 (Fig. 5*A*): anteroposterior supine position, in maximal inspiration. Blood pressure, 115/85. Film 2 (Fig. 5*B*): anteroposterior supine position, in maximal inspiration after administration of amyl nitrate, ♏ x. Well tolerated. Blood pressure, 120/90.

MEASUREMENTS IN MILLIMETERS

	a*	b	c	d	e	f
Film 1	4	6	3	2.5	1	1
Film 2	6	6	6	4.5	2	2

*See Fig. 5*C*.

Summary.—Dilatation. Total dilatation, 78 per cent. Dilatation results in loss of detail in Fig. 5*B* because the lipiodol no longer completely fills the bronchi.

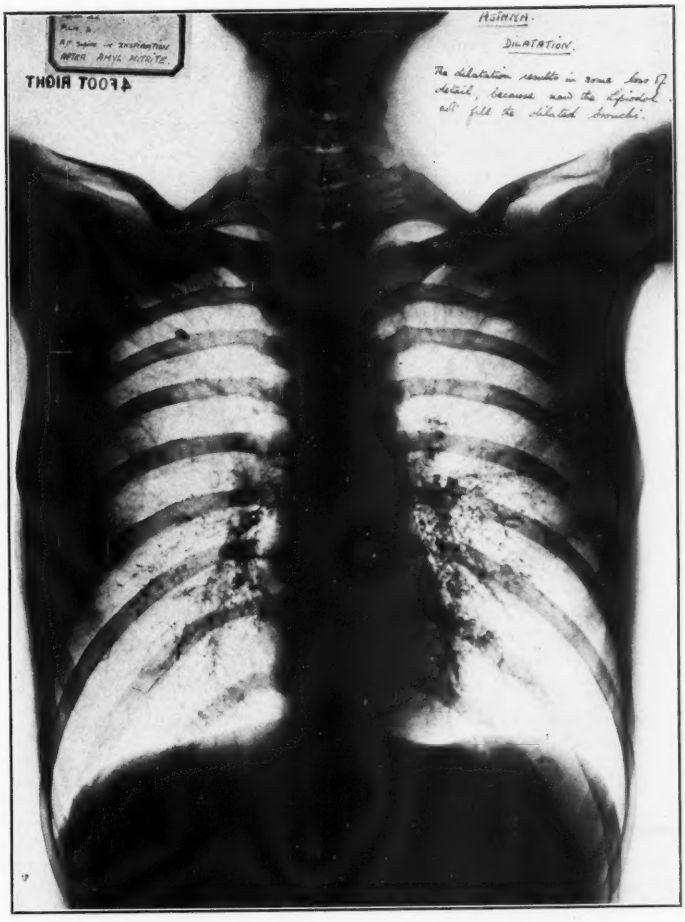

Fig. 5*B*.

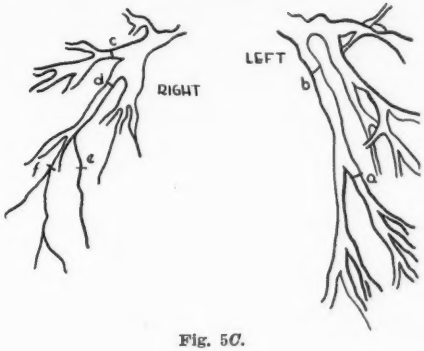

Fig. 5*C*.

TABLE II

CASES SHOWING DILATATION

CASE NUMBER	AGE	DIAGNOSIS	PERCENTAGE DILATATION
22	30	Asthma	78
12	20	Congenital cystic disease	33
16	26	Bronchiectasis	33
24	34	No chest lesion	32
26	21	? Bronchiectasis	22
13	30	Bronchiectasis	22
23	46	No chest lesion	21
19	53	Bronchiogenic carcinoma	19
25	23	No chest lesion	17
14	46	Asthma (+ codeine gr. i)	17
18	54	Hemoptysis (origin?)	15
21	48	Chronic bronchitis	12
20	53	Bronchiogenic carcinoma	12

TABLE III

CASES SHOWING NO DILATATION

CASE NUMBER	AGE	DISEASE
5	15	Bronchiectasis
6	56	Bronchiogenic carcinoma
7	45	Bronchiogenic carcinoma
8	50	Healed lung abscess
9	46	Emphysema
10	52	No chest lesion

premedication, which upsets the experimental conditions. It is interesting to note that more dilatation occurred in bronchiectasis than in chronic bronchitis or emphysema, but here the age factor obviously plays an important part.

Surprisingly enough the blood pressure did not often fall. As already stated, it was not measured in the earlier cases, but in later cases, it fell in two, rose in three, and remained stationary in three. Yet amyl nitrite is a well-known vasodilator. Perhaps the acceleration of the pulse rate was enough in these cases to maintain the blood pressure. It is possible that the failure of the bronchi to dilate in some cases can be correlated with an abnormal response from the circulatory system, such as occurred in Case 5, such patients showing little response to the drug.

Macklin in his classical work on the anatomy of the lungs has shown that the amount of smooth muscle increases in proportion as the bronchi become smaller. It would naturally follow, therefore, that the greater dilatation after amyl nitrite occurred in the small bronchi. This has been proved in three cases: in some no dilatation at all occurs in the main bronchi, and in all, it is less in proportion than in the smaller branches; in the charts the degree of dilatation in bronchi larger than 10 mm. is contrasted with the degree in those of less size. As an aid in diagnosis the inhalation of amyl nitrite after a bronchogram has been made, has a limited application. It does appear to be of value in helping to determine the degree of a bronchial stenosis. There is no evidence to suggest that an early carcinoma of the bronchus produces

bronchospasm, but analogy with the intestine does not eliminate such a possibility. If these cases are to be studied properly, every additional diagnostic measure is of value. Bronchoscopy is rarely carried out under anesthesia deep enough to abolish a spasm of the bronchus, so that recognition of this condition if present is most readily demonstrated by the use of amyl nitrite. In Cases 19 and 20, dilatation at the site of a bronchial stenosis due to bronchiogenic carcinoma was obtained, and in Case 19 some lipiodol flowed into the lung beyond the obstruction.

THERAPY

In recent years bronchostenosis due to tuberculosis has become an important problem. There are some cases for which collapse therapy is intended, in which every effort is made to preserve the internal drainage of the cavity. In these cases, the first sign of a stenosis is often wheezing, and on bronchoscopic examination the affected bronchus is seen to be granular and edematous. Local application of cocaine and adrenaline may relieve these patients considerably; they lose their wheeze, and internal drainage is promoted. Sometimes this happy relief lasts several weeks. In this early stage, occasional use of nitrites might well serve to favor drainage without the necessity of repeating the bronchoscopy.

The administration of amyl nitrite in cases of acute massive collapse should also prove of value in helping to aërate the lung and also in avoiding the use of the bronchoscope. The problem of atelectasis is being attacked with so many weapons, ranging from the bronchoscope to helium, that a simple remedy such as amyl nitrite may be overlooked too easily.

Finally, it is interesting to observe that the bronchi will dilate even wider than they are normally at the end of a maximal inspiration. This represents the reserve of the bronchial tree in forced ventilation and is noticeably more in young individuals.

Returning to the work of Thomas Fraser, his observations showed that asthma was relieved by amyl nitrite, but whether this relief was due to dilatation of the bronchi or to suppression of bronchial secretion he was unable to state. Both factors, spasm of muscle and secretion of bronchial glands, are important in allergic asthma. Adrenaline will lessen both; nitrites will only prevent the spasm. But the interest in the action of nitrites lies not so much in their use in asthma as in a study of the physiology and pathology of the bronchial tree. There is no doubt that in amyl nitrite we have a drug which produces relaxation of the bronchial muscle, and this action may assure it a place in the treatment of diseases of the respiratory system.

SUMMARY

1. The effect of amyl nitrite on the bronchial tree has been studied in dogs and in man.

2. In man, in most cases, dilatation of the bronchi was secured.

3. Younger patients showed the greater dilatation, and the smaller bronchioles dilated more than the large bronchi.

4. The diagnostic value of this test is discussed.

5. It is suggested that the drug may be of use in cases of bronchostenosis and in cases of atelectasis.

This work was carried out in the Chest Service of the Barnes Hospital, Washington University, St. Louis, Mo. The problem was suggested by Professor Evarts Graham, who placed his cases at the writer's disposal. To him, and to Dr. Sherwood Moore, I wish to express my thanks for their continued interest and many kind acts.

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SURGICAL CORRECTION OF CONGENITAL ATRESIA OF THE ESOPHAGUS WITH TRACHEO-ESOPHAGEAL FISTULA

Case Report

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CONGENITAL atresia of the esophagus with a tracheo-esophageal fistula is a developmental anomaly incompatible with life. Death invariably occurs in the first week of life due to aspirational pneumonia and dehydration. Operative correction of this anomaly in order to be successful must provide for (1) a permanent means of administering nourishment and (2) protection to the lungs from further aspiration of mucus into the trachea from the pharynx and upper esophagus as well as through the fistula from the lower esophagus and stomach.

Simple gastrostomy, although it provides a means of feeding the child, hastens death because of aspiration of gastric contents through the lower esophagus into the trachea. Leven[1] has adequately discussed the problems involved in attempting to keep these infants alive. He kept one alive for ninety-eight days and another for fifty-three days by attacking the fistula and the atresia indirectly. He performed gastrostomies in such a manner as to prevent aspiration of gastric contents into the lungs through the lower esophageal segment and then carefully aspirated secretions collecting in the mouth and throat.

Operations have been devised to attack the fistula directly through a thoracic approach. Lilienthal[2] suggested that in certain cases an anastomosis of the esophagus might be made after the lower segment had been freed from the trachea. Richter[3] designed an operation for cure of this anomaly. Under local anesthesia he opened the stomach, a guide was passed into the esophagus and along the guide a catheter was inserted into the trachea through which ether vapor could be passed under positive pressure for anesthesia. The right thorax was then opened widely and the esophagus tied off at the junction with the trachea. Following closure of the thorax, a gastrostomy was performed. Richter also suggested that an anastomosis of the esophagus might be feasible in some cases. He performed the above mentioned operation on two infants but both died within twenty-four hours following operation. The operation he performed would provide an avenue for nourishment but does not remove the danger of aspiration from secretions in the pharynx. His procedure also involves an intrapleural operation with all its accompanying complications. Iglauer[4] proposed a two-stage operation which would more nearly meet the problems involved than the operation tried by Richter. He suggested as a first stage a cervical esophagostomy on the right performed under local anesthesia.

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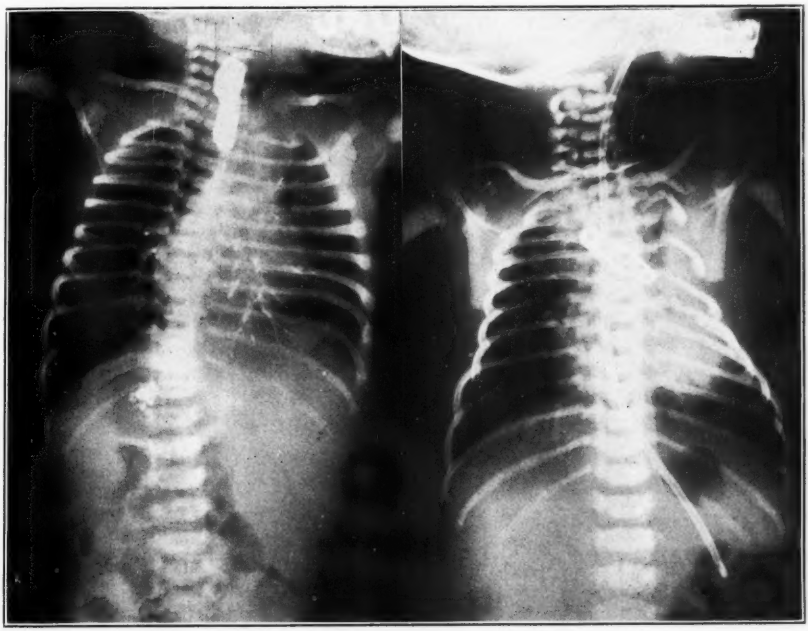
At the second stage the pleural cavity was to be opened through the sixth intercostal space, the lower esophagus tied off close to the trachea, and its open end sutured to the anterior angle of the thoracic wound during closure of the chest. This would provide an esophagostomy for feeding. An essential part of the operation would be ether anesthesia under positive pressure through an intratracheal catheter. It was proposed to do an antethoracic plastic operation later to connect the two esophageal segments. This program would take care of the upper esophageal segment, but otherwise it is open to the same objections raised above with regard to Richter's operation. Bohrer[5] performed an operation which was similar to the second stage of the proposed Iglauer procedure. He evaded the danger of an open thorax by approaching the fistula extrapleurally after resecting the fourth cartilage and a portion of the rib on the right. The operation was done under local anesthesia. The child died in twelve hours, which was to be expected since the child was premature and had other congenital deformities. An operation very similar to that proposed by the author was performed by Samson.[6] He made a curved parascapular incision on the left, resected 5 centimeter segments of the third, fourth and fifth ribs posteriorly, cut the intervening muscle bundles, and stripped the apex of the lung out of the dome of the chest in the extrapleural plane. He then severed the esophagus from the trachea, closed the fistula, and did an end-to-end anastomosis of the esophagus over a No. 18 French catheter passed through the mouth into the stomach. The wound was loosely closed with drainage. Nitrous oxide oxygen anesthesia was used. The baby died twenty-seven hours following operation. This baby was twelve days old at the time of operation and was undoubtedly in worse shape than the case presented here which accounts for the lack of partial success. Samson's operation differed from the author's in the type of incision and in the total length of rib removed but in all other details was similar. As Samson's case had not been reported the author was not aware that this type of approach had been used at the time the operation reported here was performed.

Operations devised to attack the anomaly directly through a thoracic approach have been thought to carry a prohibitive mortality. The purpose of this paper is to report a case in which an operation directly attacking the fistula was successfully performed. Unfortunately a reaction from an elective blood transfusion directly resulted in death on the twelfth postoperative day. It is felt, however, that the surgical management of this case met the problems presented and that such management in similar cases will offer a reasonable chance of restoring normal anatomic relationships compatible with future health.

REPORT OF CASE

C. R. M., male infant, three days old, was admitted to The Baylor University Hospital on Sept. 23, 1938. The birth weight was eight pounds. The admission

weight, however, was six pounds, eight ounces. A diagnosis of tracheo-esophageal fistula was made from the history of choking when the child attempted to nurse and excessive regurgitation of mucus. The diagnosis was confirmed by x-ray studies with a barium meal (Fig. 1*A*) and a bronchoscopic examination. The upper esophageal segment ended in a blind pouch at the level of the second thoracic vertebra. The lower segment opened widely into the trachea one centimeter above the tracheal bifurcation.



A. *B.*

Fig. 1.—*A*, Roentgenologic study after ingestion of barium. Note barium in blind upper esophageal segment, in bronchial tree, and in stomach. As there was total atresia of the upper segment of the esophagus the barium reached the stomach by way of the trachea and lower esophageal segment, which were united by a fistula. *B*, Roentgenologic appearance of chest on eleventh postoperative day.

The baby was placed face downward on a Bradford frame in a steep Trendelenburg position. Fluids were administered by rectum. A 90 c.c. transfusion of whole blood was given the day following admission. Aspiration of mucus at the time of bronchoscopy and postural drainage resulted in partial clearing of the aspirational pneumonia present upon admission. The temperature on the morning following admission was 100° F. as compared with the admission temperature of 105° F. The second morning following admission the temperature was subnormal, and as the child was well hydrated and the pulmonary fields were clear, the patient was considered to be ready for operation.

OPERATION

The child was strapped to the Bradford frame in the prone position. A vertical incision was made 2 cm. lateral to the spine in the left posterior chest extending from the second to the sixth ribs inclusive. Small segments of these ribs were removed mesial to their angles. The intercostal muscles, vessels, and

nerves were doubly ligated and cut. The posterior mediastinum was entered by stripping the parietal pleura from the posterior rib stumps and the bodies of the vertebrae. To gain exposure the first two intercostal arteries were ligated and cut close to the arch of the aorta. The anomalous esophagus and trachea were freed by dissection. During this dissection both vagi were identified and protected. A ligature was placed around the lower segment of the esophagus near its junction with the trachea, thereby closing the fistula. The esophagus was cut distal to the ligature. The upper esophageal segment was then identified and opened. A No. 8 French soft rubber catheter was passed through the nose down through the upper esophagus and, by way of the lower esophagus, into the stomach. A double-row, end-to-end anastomosis of the esophagus was performed over the catheter, using fine tanned catgut. Since the esophageal anastomosis could not be trusted to remain tight the wound was packed with vaseline gauze.

Fig. 2.—When the operative site was exposed at autopsy the catheter could be seen lying in a track made up of granulation tissue. This track had no epithelial lining. The anastomosed esophageal ends had separated for a distance of 13 mm. Much of the granulation tissue was wiped away, and the esophageal ends became further separated in the course of the autopsy and during the period the specimen was in fixing solution before the photograph was made.

Adequate anesthesia consisted of local infiltration of 0.5 per cent procaine solution except during the intramediastinal part of the operation when open drop ether was used. The operating time was three hours.

POSTOPERATIVE COURSE

The baby stood the procedure very well. Another transfusion of 60 c.c. whole blood was given four hours after the operation. Postoperative feedings were

carried out through the catheter. The pack was removed from the wound forty-eight hours after the operation. The following day mucus appeared on the dressing indicating an esophageal opening. Thereafter there continued to be mucus, exudate, and food on the dressing. A bronchoscopy was done on the fourth postoperative day to relieve an atelectasis of the left lung. The temperature which reached 105° F. following the operation gradually fell until it leveled off between 100° and 101° F. on the tenth postoperative day. The baby seemed to be making steady improvement. Its weight increased to nine pounds. Because of the continued temperature elevation a transfusion of 50 c.c. of citrated blood was given on the twelfth postoperative day. Respiratory difficulty, cyanosis, and hemoglobinuria developed immediately at the conclusion of the transfusion, and death occurred five hours following the transfusion.

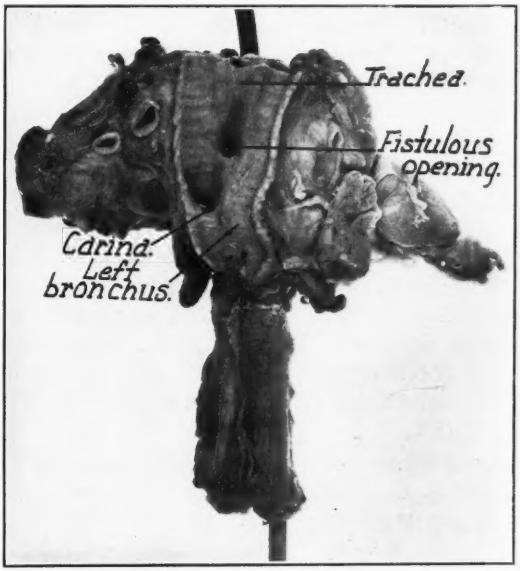


Fig. 3.—Trachea and left bronchus have been opened to show position of the closed fistulous opening 1 cm. above carina.

AUTOPSY

When the operative site was exposed, the catheter could be seen lying in a track made up of granulation tissue (Figs. 2 and 3). This track had no epithelial lining. The anastomosed esophageal ends had separated for a distance of 13 mm. The wound was well drained, there being no collection of free pus. The esophageal opening into the trachea was closed and the stump buried in granulation tissue. There was extensive bilateral pneumonia. In the right lower lobe there were two bronchiectatic abscesses 5 mm. in diameter. Microscopic examination of the kidneys showed the collecting tubules to be choked with hematin.

COMMENT

Side-tracking procedures employing gastrostomy and the formation of cervical esophageal fistulas have so far proved unsuccessful in keeping alive infants having atresia of the esophagus with tracheo-esophageal

fistula. If this procedure should prove temporarily successful the surgeon would be confronted with a child doomed to gastrostomy feedings unless extensive plastic operations for the formation of an ante-thoracic esophagus were later carried out. A direct attack upon the fistula such as described in this report is feasible and if successful should result in a condition of normal esophageal function and health.

An extrapleural approach to the esophagus and trachea not only gives adequate exposure but also provides for drainage of the site of the esophageal anastomosis. The placing of a soft rubber T-tube had been intended in the case reported, so that one short arm would be in the upper esophagus and the other in the lower esophagus (after this had been severed from the trachea); the long arm of the T-tube was to have been brought out through the wound to serve both as a drain and as an inlet for feeding. A No. 12 French catheter would nicely fit in an infant's esophagus. The use of the T-tube would reduce the danger of the infant's developing otitis media which is a frequent complication of an indwelling nasal tube. A T-tube could be left in place until all infection had subsided and an epithelialized track had developed. Removal of the tube would leave an esophageal fistula draining through the back which should close readily if an epithelialized track had been established. In cases in which the esophageal ends cannot be easily approximated, a flap could be fashioned from the hypertrophied upper segment to bridge the gap so that there would be intact mucosa along one part of the circumference of the esophagus. This would prevent the later development of complete atresia of the esophagus following the removal of the T-tube.

The aspirational pneumonia which is always present by the time congenital atresia of the esophagus with tracheo-esophageal fistula has been diagnosed is the greatest barrier to the patient's recovery. The closure of the fistula and the surgical opening of the closed upper segment of the esophagus virtually eliminate the danger of further aspiration of mucus into the lungs. There were extensive bilateral pneumonia and atelectasis still present twelve days after operation in the case reported here. The baby's temperature, however, was falling and there was no evidence of cyanosis or respiratory difficulty prior to the transfusion reaction. Also roentgenologic studies of the chest (Fig. 1*B*) the day before death showed the lungs well aerated except near the site of operation where pleural thickening obscured the underlying field. Whether or not the pneumonia would have finally cleared is not known. The chance of its clearing was, however, certainly better with the tracheo-esophageal fistula closed.

Ample time should be spent before operation not only to study the case from the standpoint of the surgical problem but also to prepare the infant for operation. During this period the dehydration can be relieved by the giving of fluids by rectum and by vein. A transfusion

of whole blood will greatly improve the baby's condition. Postural drainage with the child face downward in a steep Trendelenburg position will tend to prevent further aspiration of secretions from the mouth into the lungs and help to clear the pneumonia already present. A bronchoscopic and esophagoscopic examination is necessary not only to determine the exact anomaly present but also to clear the trachea and bronchi of secretions. Roentgenologic studies of the esophagus, trachea, and bronchi, after the ingestion of barium, give valuable and necessary information but carry the hazard of adding to the pneumonia due to the aspiration of barium into the bronchial tree. A barium study should not be carried out unless it can be closely followed by bronchoscopy. The operative correction of the anomaly should be performed as soon as the child's condition has been improved as much as possible.

CONCLUSIONS

Congenital atresia of the esophagus with tracheo-esophageal fistula can be corrected through an extrapleural thoracic approach. The operation allows for drainage of the posterior mediastinum which is necessary because leakage of the esophageal anastomosis will inevitably occur. Success with this type of correction will result in normal anatomic relationships. Bronchoscopy and postural drainage will greatly aid in clearing the aspirational pneumonia. Closure of the tracheo-esophageal fistula at the time of operation lessens the danger of further aspiration of secretions into the lungs.

SUMMARY

1. An original plan for the surgical management of congenital atresia of the esophagus with tracheo-esophageal fistula is described.

2. A case is presented showing that a direct attack upon the fistula is feasible.

Appreciation is expressed to Dr. W. H. Bradford and Dr. C. E. Patterson for their clinical assistance; to Dr. J. R. Maxfield, Jr., for his assistance in obtaining roentgenologic studies; and to Dr. R. A. Kooken, Hamilton, Texas, the family physician, for his prompt recognition of the anomaly.

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ESOPHAGUS AFTER PNEUMONECTOMY

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THE complete removal of one lung necessitates many anatomic and physiologic adjustments. In this article we shall present the findings of a study of the esophagus in six patients who have had total pneumonectomy at the University of Michigan Hospital. These operations were performed by Dr. John Alexander and Dr. Cameron Haight. The indications for pneumonectomy were carcinoma of the bronchus, chronic pulmonary suppuration, and mixed tumors of the bronchus. Roentgenologic examinations of the esophagus were made from six months to four years after the pneumonectomy had been performed. At that time all the patients were in good health.

EFFECT OF PNEUMONECTOMY ON MEDIASTINAL STRUCTURES

The position of the mediastinum is influenced by the relative pressures in the opposing hemithoraces. Any alteration in these relative pressures will cause a compensatory adjustment in the position of the mediastinal partition. The normal mediastinum is quite mobile, but disease processes may diminish this flexibility. Certain surgical procedures, such as pneumonectomy, and certain pathologic processes, such as massive atelectasis of the lung, which reduce the pulmonary volume in one hemithorax, cause compensatory adjustments. There will be elevation of the ipsolateral leaf of the diaphragm, narrowing of the intercostal spaces with diminished respiratory excursion, and displacement of the mediastinum toward the involved side. Of these three compensatory adjustments, deviation of the mediastinum is the most important. Apart from mediastinal displacement, a marked difference of pressure in the hemithoraces may cause herniation of one lung into the opposite hemithorax through the normally weak places in the mediastinum. After complete removal of one lung, extreme examples of this adjustment may be seen. The degree of mediastinal displacement and herniation will be less if a thoracoplasty has been performed after the pneumonectomy.

The various mediastinal structures do not share equally in this displacement. The degree of fixation of each structure determines to what extent its position is altered. Also, a particular structure may readily be displaced to one side but less readily in the opposite direction. Rienhoff[1] has described the displacement of the heart, aorta, and trachea in post-mortem studies following pneumonectomy.

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The displacement of the various mediastinal structures consists of a lateral shift associated with varying degrees of rotation. The degree to which an organ can rotate depends on its attachments. The heart rotates with the aorta acting as the axis. After a left pneumonectomy the cardiac apex moves to the left and rotates posteriorly. Because of its relation to the great vessels, the heart is less able to rotate far to the right to compensate for ablation of the right lung. The remainder of the tracheobronchial tree also undergoes lateral displacement and rotation, but to a lesser degree than does the heart. Because of the fixation of the esophagus and the continuity of the thoracic esophagus with its cervical and abdominal portions, no appreciable rotation of the esophagus can occur. For the same reason, the lateral displacement of the esophagus might be less than that of some of the other mediastinal structures.

Blalock[2] found marked displacement of the esophagus in three dogs after pneumonectomy without paralysis of the diaphragm. In one dog, after pneumonectomy and paralysis of the ipsolateral leaf of the diaphragm, there was much less esophageal deviation. The degree to which the animal experiments can be applied to man is questionable because of the difference in the anatomy of the mediastinum of dogs and of men.

As the mediastinal structures are displaced laterally and posteriorly, there is compensatory enlargement of the remaining lung with some rotation of the tracheobronchial tree. The anteromedial portion of the lung protrudes in front of the mediastinal structures. As a result, a considerable part of the anterior portion of the thorax is occupied by pulmonary tissue. Rienhoff[1] has also demonstrated that following left pneumonectomy, a lappet of the posteromedial portion of the right lung protrudes between the aorta and esophagus. This protruding portion of lung is not sufficient in amount to cause much esophageal displacement.

ANATOMY OF THE ESOPHAGUS

The normal thoracic portion of the esophagus maintains a generally vertical direction. In its upper portion it is near the anterior surface of the upper thoracic vertebrae and approximately in the midline. It then passes behind the left bronchus at the level of the fifth thoracic vertebra. In the midchest it lies anterior to, and at the right of, the aorta. Near the tenth thoracic vertebra it sweeps in front of the aorta to the left of the median line. The normal deviations of the esophagus from the median line are rather slight and always in gentle curves. Areolar tissue and muscle fibers maintain a moderately close union between the esophagus and its neighboring structures. This is particularly true of the esophageal attachment to the left bronchus and, to a lesser degree, to the right bronchus. There are, in addition, ir-

regular attachments to the pleura and pericardium. The right mediastinal pleura extends posterior to the right border of the esophagus in part of its course. Because of these anatomic attachments between the esophagus and other mediastinal organs, the esophagus may be displaced with them by pathologic processes or following surgical procedures.

POSITION OF ESOPHAGUS AFTER PNEUMONECTOMY

Each of the six patients was fluoroscoped in the upright position while the esophagus was outlined with opaque media. Observations were made anteroposteriorly, laterally, and at oblique angles. Roentgenograms were then made with the patient supine. The stomach was

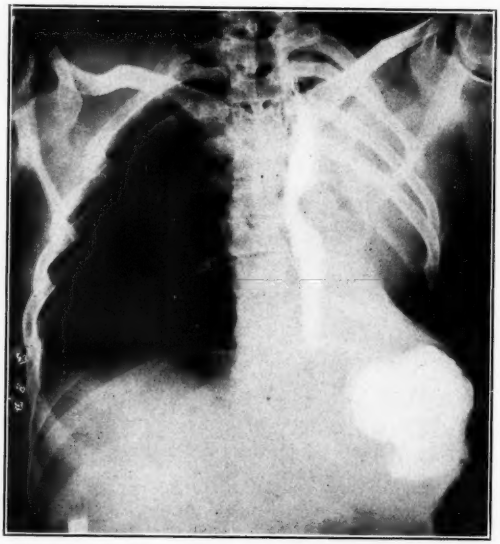

Fig. 1.—Left pneumonectomy followed by partial thoracoplasty was performed twenty months before this roentgenogram was made. The esophagus is only slightly displaced and shows the indentation caused by the aortic arch.

also studied. The anatomic position of the esophagus and the roentgenoscopic evidence of esophageal function were noted. The findings were as follows:

1. Marked displacement of the esophagus was not observed in any patient. In most cases the esophagus deviated to the side operated upon at the thoracic inlet and then had a straight, vertical course to the level of the tenth thoracic vertebra where it curved to the left to join the stomach (Fig. 1).

2. There was somewhat more deviation of the esophagus to the side operated upon in patients who did not have a thoracoplasty following pneumonectomy than in those who did (Figs. 2 and 3). In one

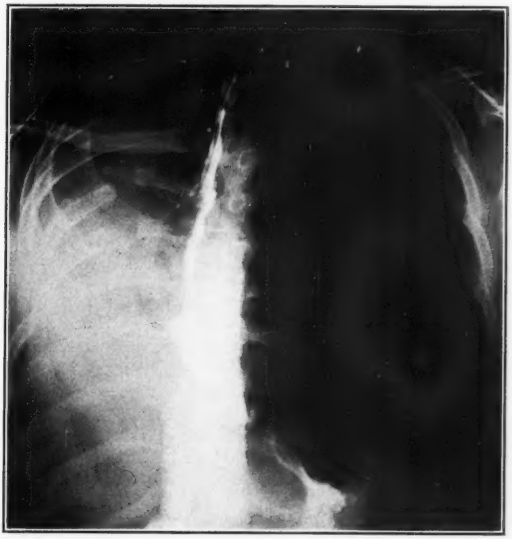

Fig. 2.—Right pneumonectomy without drainage or infection of the pleural cavity was performed one year previously. The esophagus curves toward the right side.

Fig. 3.—Right pneumonectomy was performed more than three years previously. Thoracoplasty was performed later because of empyema. The esophagus is in a relatively normal position.

instance of left pneumonectomy followed by prolonged pleural infection and thoracoplasty, no displacement of the esophagus was present. In general, the greater the mediastinal deviation, the more the esophageal displacement.

3. In no instance was acute angulation or deviation of the esophagus noted at any point in its course. It might be expected that the organization and fibrous tissue replacement of the fluid in the upper thorax after pneumonectomy without drainage of the pleural cavity might result in a pull on the esophagus, but nothing to indicate this was observed.

4. No significant difference in the degree of esophageal displacement was noted in the cases studied within one year after pneumonectomy as contrasted with those cases studied several years after removal of the lung. The number of cases studied, however, was not sufficient to establish this finding as a necessarily constant one.

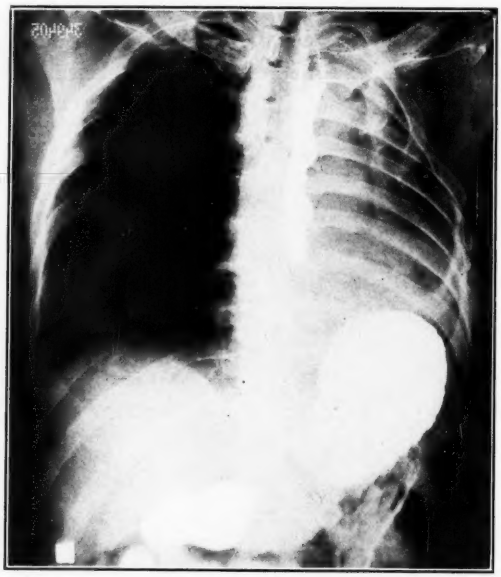

Fig. 4.—Left pneumonectomy without drainage or infection of the pleural cavity was performed four years previously. The esophagus deviates to the left at the thoracic inlet and then descends vertically just to the left of the vertebral bodies.

5. One patient who was observed more than three years after right pneumonectomy for carcinoma of the right lung had slight widening of the esophagus on roentgenoscopic examination. This patient had very slight displacement of the esophagus toward the right. She had had a thoracoplasty for chronic empyema following the pneumonectomy (Fig. 3).

6. Examination of the esophagus in lateral projection did not demonstrate any appreciable forward displacement of the esophagus after pneumonectomy. The amount of right lung which protrudes toward the left side posterior to the esophagus is small and not sufficient to cause significant forward esophageal displacement.

7. Following left pneumonectomy, the left leaf of the diaphragm may be elevated even if the phrenic nerve has not been paralyzed; this elevation results in a high position of the stomach. In such cases a considerable portion of the stomach is seen to lie above the level of the gastroesophageal stoma when the patient is in the upright position (Fig. 4).

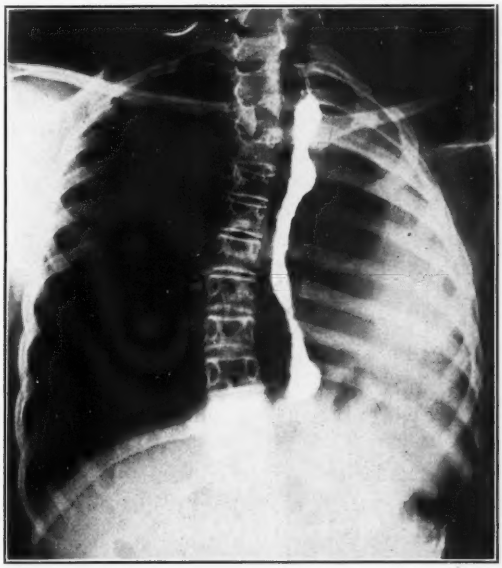

Fig. 5.—Roentgenogram of 18-year-old female fourteen months after left pneumonectomy. There is moderate displacement of the esophagus to the left; the true displacement is exaggerated by the rotation of the patient on this roentgenogram. The right lung has partly filled the left hemithorax.

8. Although in one case there was considerable curving to the left of the lower esophagus as a result of the elevation of the stomach following left pneumonectomy, no angulation of the esophagus or delay in the passage of barium was noted.

9. In one patient left pneumonectomy was carried out because of an intrabronchial tumor with extensive pulmonary destruction and moderate diminution in the volume of the left lung. In the preoperative roentgenograms the esophagus was displaced to the affected side. There was no further displacement of the esophagus following pneumonectomy (Fig. 5).

ESOPHAGEAL SYMPTOMS FOLLOWING PNEUMONECTOMY

None of the patients examined had any dysphagia following pneumonectomy. A few patients volunteered the information that on swallowing fluids they were conscious of a sensation as though the fluids deviated toward the side from which the lung had been removed. This sensation was present in cases of either right or left pneumonectomy whether or not thoracoplasty had been performed, and it was present in instances in which roentgenologic examination of the esophagus revealed little displacement and no acute angulation of the esophagus. There was no roentgenoscopic evidence of delayed esophageal emptying in these patients. The one patient who showed slight widening of the esophagus also experienced this sensation of esophageal displacement; she had had a right pneumonectomy more than three years previously (Fig. 3). This sensation of esophageal deviation caused no real discomfort in any case.

No patient following pneumonectomy had any regurgitation immediately after the swallowing of food or fluid. One patient, however, who had had a left pneumonectomy, had occasional episodes of vomiting after meals. Roentgenoscopic examination of his esophagus and stomach revealed no organic obstruction or disturbance of function. Other examinations also failed to reveal the cause of the vomiting.

SUMMARY

1. The effect on the esophagus of the complete removal of one lung has been studied in six patients. The esophagus was examined roentgenologically in each case from six months to four years after pneumonectomy.

2. No marked angulation or marked displacement of the esophagus was observed in any patient; moderate displacement toward the side of pneumonectomy was noted in some.

3. No disturbance of esophageal function was observed.

4. No significant esophageal symptoms following pneumonectomy were noted.

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LIPIODOL IN THE PERICARDIUM

An Experimental Study

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THE historical development of lipiodol began in 1848, when Marchal (de Calvi)[1] proposed the use of an iodized oil for the slow administration of iodine in antisyphilitic therapy. German chemists acted upon this proposal, the result being a preparation known now as iodipin, a chloroiodized sesame oil containing 25 per cent iodine by weight. This preparation had some therapeutic vogue until a French syphilologist, Lafay,[2] in 1901, produced an iodized oil by the saturation of poppy seed oil with hydriodic acid. The preparation was called lipiodol. Lafay considered it to be less irritating than iodipin and more stable; it contained 40 per cent iodine by weight, organically bound. Lipiodol rapidly gained a following in France for the treatment of various internal disorders, where iodine medication was indicated, and particularly where slow absorption and small dosage were desirable because of sensitivity to iodine. Lipiodol formed the subject of an extensive doctorate thesis by Paul Martin of Lyons in 1904.[3]

The use of repeated parenteral injections of lipiodol and its tendency to persist for a long time in the tissues led to the accidental discovery during roentgenographic examination of its highly radiopaque property. Sicard and Forestier[4] were the first to avail themselves of this fact. They injected lipiodol into the epidural space as a treatment for lumbago and sciatica and observed its dissemination up and down the spinal extradural space. They injected it intrathecally, and, observing that it was well tolerated by the meninges, they essayed its injection into the tracheobronchial tree where the most remarkable contrasts were obtained.

Antedating the work of Sicard and Forestier by five years, Waters, Bayne-Jones, and Rowntree[5] in 1917 injected an emulsion of 10 per cent iodoform in olive oil into the bronchial trees of dogs, obtaining satisfactory roentgenograms in some instances, but observing the pro-

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duction of a proliferative pneumonitis in three animals and suffocation from deliberate overdosage in three others. In 1918 Chevalier Jackson insufflated dry bismuth subcarbonate powder into the bronchi, and in 1920 Lynch and Stewart used a preparation of bismuth in oil.

The increasing success of lipiodol as a contrast medium in the chest culminated in the monograph of Chandler and Wood[6] in 1928 and suggested its possible use in other fields. In 1924 Lanari and Squirru[7] reported the accidental visualization of the biliary tract following injection of a hydatid fistula. In the following year, Coffe of Lyons[8] reported four cases in which he had deliberately injected lipiodol into biliary fistulas, and he was the first to recommend its use in the roentgenographic study of the common duct at the operating table.

Fiessinger and LeMaire[9] in 1925 injected lipiodol into the pericardial sac of a patient suffering with tuberculous pericarditis and effusion in a vain attempt to influence the course of the disease and to prevent the formation of adhesions. This experiment was repeated under similar circumstances by Castex, Carelli, and Gonzales[10] in 1926. These authors suggested the possibility of outlining the pericardial sac by roentgenograms through various body planes. On the basis of the above work, Chandler and Wood[6] hinted at the possibility of exploring the pericardium by lipiodol injection for the diagnosis of adhesive pericarditis.

Obviously, the pericardium has resisted attempts at contrast roentgenography because of the well-known dangers of puncture by a needle when the heart muscle and coronary vessels are not protected by a considerable layer of fluid exudate. When the latter is encountered, withdrawal of fluid and substitution of air permits of some diagnostic help in roentgenography. The safe introduction of lipiodol intrapericardially in cases not associated with hydropericardium would seem to necessitate a direct surgical exposure by means of a limited anterior chondrectomy. This would be justifiable only if definite information regarding adhesions and their extent, tumors, and the localization of foreign bodies could be obtained (usually as an immediate preliminary to operative intervention); and only if the injection could be proved to be innocuous with respect to the effect on the myocardium and pericardial tissues. It is evident from the early French experiments that lipiodol is remarkably free of local reaction when injected subcutaneously or intramuscularly. Its absorption is very slow, free iodine appearing in the urine not until from three to five days after injection and persisting for as long as six months.[3] The experiments of Ballon[11] on rabbits and of others indicate a similar tolerance by the lung. It is the purpose of this paper to study the effect of lipiodol when injected into the normal pericardial cavity.

METHODS

Ten adult cats in good physical condition were used; they weighed between 2 and 3 kg. Anesthesia was induced by intraperitoneal injection of nembutal (35 mg. per kilogram) followed by the insertion of an intratracheal catheter and insufflation of air-ether mixtures. With aseptic precautions, a short left intercostal thoracotomy was made, the lung retracted, and the parietal pericardium exposed. The pericardium was lifted with a fine forceps and from 0.5 c.c. to 1 c.c. of lipiodol injected with a No. 22 needle. The puncture point was ligated with No. A silk, the lung reinflated, and the chest wound closed in layers, using the same suture material; the wound was protected with collodion and gauze. Within an hour after operation the cat was fluoroscoped, and roentgenograms were made to determine the presence and extent of lipiodol in the pericardial sac (Figs. 1 and 2).

Fig. 1.

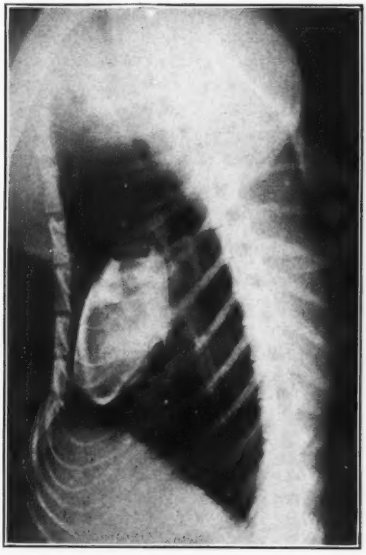

Fig. 2.

Fig. 1.—Oblique roentgenogram of chest, approximately one hour after injection of 0.5 c.c. lipiodol into the pericardial sac.

Fig. 2.—Lateral roentgenogram of chest, thirty minutes after injection of 0.75 c.c. lipiodol into the pericardial sac.

The animals were then maintained on an ordinary diet. They survived in good condition with one exception. This animal developed after three weeks a pansinusitis and tracheobronchitis of the type which arises spontaneously in caged cats. The other subjects remained well and were killed at postoperative periods ranging from 3 weeks to 12 months as follows: 24 days, one; 6 weeks, one; 9 weeks, one; 15 weeks, one; 19 weeks, one; 26 weeks, one; 52 weeks, three. On the day of death a roentgenologic examination of the chest was repeated to determine the size of heart shadow and evidence of persisting lipiodol. The fasting animal was then killed by an intraperitoneal injection of nembutal in overdosage. After preparation of the chest, the thorax was reopened with sterile precautions, the gross condition of the lungs and pleura was noted, and the pericardium was opened. Any fluid present was aspirated and cultured aerobically and anaerobically. The condition of the peri-

cardium and epicardium was described, and the heart and lungs were removed *en bloc* for preservation in 10 per cent formalin. Microscopic sections of the heart, including ventricles, auricles, and parietal pericardium, were made in all cases, and of the neighboring portions of the lung fields in several.

RESULTS

In none of the animals was evidence found of intrapericardial adhesions between pericardium and epicardium. The serous surfaces were entirely smooth and shiny without evident thickening of the pericardial supporting tissues. In three animals (19, 26, and 52 weeks' duration), there was noted one or two very small yellowish subepicardial nodules 1 to 2 mm. in diameter; these were located on the auricle close to the pulmonary veins. Microscopically these were seen to consist of phagocytic monocytes containing fat globules, surrounded by fibroblasts, rare lymphocytes, and polymorphonuclears with evidence of capillary proliferation at their base, the whole entirely covered by the mesothelium of the epicardium.

The length of time which lipiodol persisted in the pericardial sac, as indicated by the presence or absence of a positive roentgen shadow and the appearance of the pericardial fluid, varied somewhat with different subjects. The animal killed in 24 days showed approximately 2 c.c. of milky fluid. This consisted microscopically of a homogeneous emulsion of fat globules, which stained with sudan III and which were mixed with a few leucocytes and an occasional large wandering cell containing phagocytized fat particles. The 6- and 9-week specimens showed somewhat smaller amounts of the lipoid emulsion. The 15-week specimen showed no evidence of a persisting roentgen shadow and only less than 1 c.c. of serous pericardial fluid. The 19- and 26-week animals showed a persistent roentgen shadow and 2 c.c. and 1 c.c., respectively, of lipoid emulsion in the pericardial space. Of the three animals which were sacrificed after 52 weeks, two had negative roentgen findings and no evidence of emulsion in the pericardial space, and one had a faintly visible pericardial shadow by x-ray with from 1 to 2 c.c. of thin emulsion (microscopically still containing oil).

Aerobic and anaerobic cultures of the pericardial fluid at autopsy were all sterile.

In all animals histologic examination revealed the cardiac musculature to be well preserved and stained; the parietal pericardium was free of infiltration with leucocytes.

SUMMARY

Injection of a small amount of lipiodol (0.5 to 1 c.c.) into the pericardial sacs of cats permitted a clear visualization of the pericardial outlines by roentgenography without any immediate untoward effects generally or locally.

Evidence of the lipiodol as a lipoid emulsion persisted as long as six and twelve months in some animals. Following the absorption there was no residual exudate and no evidence of adhesions or pericardial thickening. The pericardial fluid remained sterile.

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